HELSINKI SCHOOL OF ECONOMICS (HSE)
Department of Accounting and Finance

THE UNCERTAIN COST FACTORS OF OIL POLLUTION

Case Global Oil Company

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ABSTRACT
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Objectives of the Study

The main objective of the study is to construct a framework outlining the different cost factors of oil pollution from the perspective of a global oil company. This study also carries out a risk analysis on these cost factors to assess their individual level of uncertainty in addition to the combined uncertainty of these cost factors. The results provided by this study will be utilised by Corporation X in its internal investment evaluation and as background information for its future marketing measures focused on global oil companies.

Methods and Data

This study can be described as an explorative case study. The theoretical background was obtained from two different fields of economic literature. These areas were environmental economics and investment risk analysis. The data required for the empirical portion of this study was gathered from interviews, publicly available information sources and the internal material of various organizations.

Results

As a result of this research four different cost factors related to oil pollution from the perspective of a global oil company were identified. The identified cost factors were oil spill clean-up costs, third party insurance costs, costs from the loss of oil and image costs. In the performed risk analysis the two most uncertain cost factors were determined to being clean-up costs and third party insurance costs. The two remaining costs factors were evaluated as having less of an impact on total oil pollution costs. In addition to the quantitative risk analysis, the numerical information was completed with qualitative information to evaluate the future development of these costs.

Key terms

environmental policy, oil pollution liability, risk analysis, event study

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ÖLJYVUOTOJEN EPÄVARMAT KUSTANNUSTEKIJÄT
Case kansainvälinen öljy-yhtiö

Tutkimuksen tavoitteet

Tutkimuksen pääasiallinen tavoite on rakentaa viitekehys, joka määrittää eri öljyvuotojen aiheuttamat kustannustekijät kansainvälisen öljy-yhtiön näkökulmasta. Tässä tutkimuksessa suoritetaan myös riskianalyysi näille kustannustekijöille, jotta voidaan arvioida sekä näiden tekijöiden yksittäistä että yhdistettyä epävarmuutta. Tämän tutkimuksen tuloksia hyödynnetään Yhtiö X:n toimesta investoinnin sisäiseen arviointiin sekä tulevaisuudessa kansainvälisiin öljy-yhtiöihin kohdistuvien markkinointitoimien taustatietona.

Tutkimusmetodit ja lähdeaineisto

Tämä tutkimus on luonteeltaan eksploratiivinen tapaustutkimus. Tutkimuksen teoreettinen taustatieto on peräisin kahdesta eri taloustieteiden kirjallisuusalueelta. Nämä kaksi aluetta ovat ympäristötalouteen ja investointien riskianalyysiin keskittyvä kirjallisuus. Empiriaosuuden muodostamiseen tarvittu tieto hankittiin haastatteluista, julkisesti saatavilla olevista tietolähteistä ja useiden organisaatioiden sisäisestä materiaalista.

Tulokset

Tutkimuksen tuloksena havaittiin neljä eri öljyvahinkoihin liittyvää kustannustekijää. Havaitut kustannustekijät olivat puhdistuskustannukset, kolmansien osapuolten varalta ylläpidettävät vakuutuskustannukset, öljyn menetyksestä aiheutuvat kustannukset ja imagokustannukset. Riskianalyysin tulosten perusteella voidaan todeta puhdistuskustannusten ja vakuutuskustannusten olevan kaikista epävarmimmat kustannustekijät. Kahdella muulla kustannustekijällä havaittiin olevan pienempi vaikutus öljyvuotojen kokonaiskustannuksiin. Kvantitatiivisen riskianalyysin lisäksi numeerista tietoa täydennettiin kvalitatiivisella tiedolla, jotta näiden kustannustekijöiden tulevaisuuden kehitystä pystyttiin arvioimaan.

Avainsanat

ympäristöpolitiikka, öljyvuotojen vahinkovastuu, riskianalyysi, event study

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INTRODUCTION

1.1 Background and Motivation for the Study

The oil spills resulting from the tanker accidents of Torrey Canyon in 1967 and Amoco Cadiz in 1978 began to shape the way international oil companies consider and prepare for the possibility of oil spills. These accidents also raised the need to compile international regimes to govern the liability of ship owners and how compensations are paid to third parity victims in oil pollution situations. The oil spill of Exxon Valdez in 1989 gave the final boost to organizing global oil spill response services in the way they are currently structured. After these incidents, the amount of attention given to the effects, both ecological and financial, of oil spills has constantly increased. Despite the massive attention given to the financial aspect of oil spills, all relevant research in this area has almost completely concentrated on the amounts of compensation paid to third party victims and analyzing the technical merits for these compensations.

This study will approach the subject of costs resulting from oil pollution from a different perspective. It is the aim of this study to outline the costs generated by oil pollution and the uncertainty related to these costs from the perspective of a global oil company. This type of research has never been done before as became evident when talking to the experts in different fields during this research process. In fact, it was noticeable that several interviewees had a rather narrow perception to the subject as a whole. Their knowledge of the different international agreements, organizations, their operations and mutual relationships was in many cases rather limited. Despite the fact that in order to understand how the total costs of oil pollution are formed, the knowledge of precisely these aspects is crucial. In this sense this research can be considered first of its kind.

A major factor in oil pollution costs are the costs generated by oil spill response. Currently the biggest global oil companies fulfil their global oil response needs by being members in Oil Response Limited (OSRL), based in Southampton. It is at present the only entity to provide such services on a global scale. Global oil companies are in need of this type of world wide service since it is a requirement of many countries that in order for an oil company to operate in said country, they need to have the preparedness to handle possible oil spill scenarios. A membership in OSRL is considered as being a sign that the necessary measures for such possibilities have been taken.

This study was carried out in co-operation and at the initiative of a Finnish company, which shall be referred to as Corporation X. It is the goal of Corporation X to develop a new concept to meet the requirements of global oil spill response in a superior way to the present day model. The ultimate goal of Corporation X is to persuade international oil companies to change from their current service provider, OSRL, to being clients of this new concept.

The financing of the new oil spill response investment will be partly based on membership and other fees from global oil companies. Even though there are also other positive cash flows, these payments are planned to form a substantial part of the required revenue. In order for Corporation X to evaluate the level of financial gain obtainable from these memberships, knowledge of the present level of oil pollution costs faced by global oil companies is necessary. In addition to receiving information of the variables contributing to oil pollution costs in the present day, the results of this study will also enable Corporation X to evaluate the possibilities of their new concept to lower these costs and thus for them having a competitive edge.

Based on the information above, the motivation for this study can be divided into practical and academic. In order to convince global oil companies of the attractiveness of the new solution, Corporation X requires concrete facts to support its marketing measures. The results of this study are going to be a part of those marketing measures, by providing both quantitative and qualitative information. In addition to acting as a base for future marketing operations, the accounting information provided by this study can also be utilised in the internal profitability evaluation of the new concept. Fees charged from global oil companies would be a major source of cash inflow for the new investment. The estimation of the overall return for the new concept requires information about the possible magnitude of these fees and the possible factors affecting the scale of those fees. The information provided by this study will aid in this estimation.

From an academic point of view, the main reason for conducting this study is that it would for its own part complete the existing field of research in this area. This holds true for two different fields of economic literature: environmental economics and investment related risk analysis. Environmental economics literature is highly concentrated on the theoretical aspect of analyzing the need for various environmental policies and the respective pros and cons of each policy on a general level. This study will concentrate on analyzing how in practice an environmental policy functions in allocating the costs resulting from environmental damage in a specific scenario. Since this research is done from the perspective of a single industry, it is able to analyze the consequences of the environmental policy in addition to the effects of different variables and their interaction in forming the total costs of oil pollution. Such a detailed approach to evaluating the different real life variables which influence global oil company environmental costs is unprecedented.

Investment related risk analysis literature is focused on two major areas, which are the survey and theoretical approaches. The results of surveys conducted concerning the benefits of risk analysis and reasons for performing or not performing formal risk analysis are rather uniform. These surveys showed that the most popular individual techniques are traditional ones such as sensitivity analysis and subjective probability estimates and in some instances also Monte Carlo simulation. It was also evident that the more sophisticated the technique, the less it was applied at least on its own. These surveys also raised several benefits from carrying out investment risk analysis, but reasons for declining such practices were as apparent. For more detailed information about these survey studies, interested readers are advised to familiarize themselves with for example the studies of Neuhauser and Viscione (1973), Mills (1988), Pike and Ho (1991) and Simister (1994).

The reasons why formal risk analysis is not carried out with investment decisions include lack of required time and resources, difficulty in obtaining realistic input estimates and the difficulty of understanding suggested techniques. In my view, these reasons coincide with the criticism of theoretically approached risk analysis research. The main criticism against theoretical studies, for example in the study of Arnold and Hatzopoulos (2000), is that they are based simplified assumptions and the possibility for their real life application is often limited. This has lead to the situation that even though theory encourages the use of formal risk analysis techniques, the number of practical applications does not match the amount of theoretical knowledge. This study will attempt to apply risk analysis into a real life business scenario, faced with the difficulties listed in previous research. The biggest of which is the lack of complete information.

As stated, this study will aid in filling existing gaps in the previously stated fields of economic literature. In addition to contributing to the knowledge of both fields individually, this study will attempt to combine the knowledge of both fields. It is the goal of this study to utilize methods presented for investment risk analysis to evaluate the individual and combined uncertainty of the variables affecting oil pollution costs.

1.2 Objectives of the Study

It is the aim of Corporation X that at a later stage this new concept will be a source of revenue for its members, i.e. the oil companies. Before the new concept is able to generate financial gain to its clients, it is the belief of the management of Corporation X that its attractiveness would lie in the cost savings it would provide compared with the currently available method of oil spill response. However, the factors affecting oil pollution costs are by nature uncertain and at this point relatively unknown to Corporation X. Consequently, it is a requirement for Corporation X to obtain more information about these variables and of their uncertainty. This information would enable them to estimate the value of their service and the possible cost savings they would be able to provide to their clientele, with a higher level of certainty.

It is the objective of this study to perform risk analysis on the costs generated by oil pollution. This risk analysis will identify all the cost factors, either direct or indirect, affecting the total costs of oil pollution, which are of importance to global oil companies. In addition, this study will analyze the individual uncertainty related to these factors and what effects their combined uncertainty might have on the overall level of oil pollution costs. As a result of the risk analysis, Corporation X will have available both qualitative and quantitative information to be utilised in the further development of their concept for oil spill response service.

The main research problem for this study is the following: What are the cost factors generated by oil pollution and what is the uncertainty related to them? And the main objective of this research is to provide Corporation X with information about the different cost factors related to oil pollution and about the present state of global oil spill response services in order for them to evaluate the possible advantages provided by their investment. This paper will meet its primary objective by completing the following sub-objectives:

1. The description of the theoretical background of the environmental policy related to oil pollution and how oil pollution related costs are allocated in practice.
2. To develop knowledge of theories presented in literature concerning investment risk analysis.
3. The description of the present state of oil spill response services.
4. To analyze the uncertainty of the oil pollution cost factors and the effects of their combined uncertainty.

1.3 Research Methods and Data

The field of management accounting research can be divided between normative and positive research. Normative research is concerned with creating prescriptions for rational behaviour aimed at utility maximization. The aim of positive accounting research is to explain and predict how variables interact in the real world. (Scapens 1990, 260–261)

This study can be categorized as positive accounting research, because its aim is to describe the different variables contributing to the total costs of oil pollution and how the interaction between these variables can affect the total level of costs. It is not possible in the scope of this study to advise Corporation X on how the information provided by this study can be utilised and how they can influence the different cost factors with their own actions.

The terms case studies and fieldwork can be used interchangeably when referring to *"...management accounting practices in the field of activity in which they take place."* This type of research implies a single unit of analysis, but this unit may be comprised of only one company or an aggregated unit of analysis. (Scapens 1990, 264) The latter is true in the context of this research. This study explores the framework which determines the costs caused by oil pollution to global oil companies. These costs can and will naturally vary between companies due to individual company specific factors, but the empirical framework constructed in this study can be considered as the basis from which more detailed evaluation in the context of an individual company can be started from.

Even though case studies are all unified by the underlying concept of studying a specified phenomenon in practice, different types of case studies can be utilised in varying forms (Scapens 1990, 264):

Descriptive case studies. These types of case studies focus on currently existing systems, procedures and techniques and have the objective of providing a description of them.

Illustrative case studies. These studies aim at illustrating what new and possibly innovative practices have been developed by particular companies.

Experimental case studies. Experimental case studies explore the difficulty of implementing new techniques developed by researchers into the use of practitioners and what benefits can be derived from these new techniques.

Exploratory case studies. Case studies can be used to explore the reasons behind a phenomenon. It is the aim of these studies to make generalizations, which can be further analyzed at a later stage.

Explanatory case studies. These case studies attempt to understand and explain a specific phenomenon from the bases of existing theories or if necessary modified ones.

Separating and categorising different types of case studies is not necessarily a straightforward process. For example the line between an exploratory and an explanatory case study can be thin. (Scapens 1990, 265)

This study can be described as an explorative case study. The explorative nature of this study deals with the outlining of the various parties and international agreements attributable to forming oil pollution costs and how the relationships between these entities contribute to the total costs of oil pollution from the perspective of an individual oil company, in the present day situation. One of the main characteristics of explorative research is that it aims to form an understanding of a previously relatively unknown phenomenon (Uusitalo 1991, 62). As previously mentioned, a study combining all the different elements of oil pollution costs has never before been done to the best of knowledge of the people interviewed during this research process or myself.

The explorative nature of this study is further described by its aim to be a stepping stone into further research in this field. It is one of the main objectives for exploratory studies to lay a foundation for more rigorous empirical testing and generate ideas for further research (Ryan et. al. 1992, 115). It is not the purpose nor would it be possible in the scope of this study to create a complete risk analysis of the field of oil pollution. This study will provide the most accurate and detailed analyses possible in the current situation, but the level of reality of the phenomenon under review can be increased by further research and increased co-operation of the relevant parties.

The four main types of threats to the validity and reliability of a field study are observer-caused effects, observer bias, data-access limitations as well as complexities and limitations of the human mind (McKinnon 1988, 37). Of these four the two most relevant threats for this study were observer-caused effects and data-access limitations. The first threat was relevant with the qualitative information used in this study and process of gathering that information. Data-access limitations were relevant in obtaining necessary quantitative information. Observer bias was not a factor affecting the outcome of this study, because this study was carried out by an independent party, for the precise reason, that the results of this study could be considered neutral. The threat of limitations of the human mind was not a factor in carrying out this research any more significantly than on any other research at this level.

Observer-caused effects refer to the reactions caused by the observer being involved in the study. Examples of such effects may include participants altering their behaviour or conversation, because of the observer's involvement in such a way that the researcher is not able to obtain results equivalent to a natural state. (McKinnon 1988, 37) The possible effects of this threat were attempted to be minimised in the gathering of data by not informing the people being interviewed, that this study was being conducted on behalf of a commercial company. This information was only revealed if it was directly asked. This approach was chosen to try and ensure that the answers obtained were as realistic as possible and to eliminate the effects of bias.

A researcher may experience three different types of data access limitations. Firstly, the researcher may be restricted to observing the phenomenon of interest for a limited period of time and be unaware of the occurrences outside of that particular time frame. Secondly, the researcher may accidentally witnessing an "atypical" time or thirdly, the researcher may experience restrictions in receiving access to documents, events or people relevant to the study. (McKinnon 1988, 38) The last one was true for this study. Access was not granted to certain information, which was considered classified on the part of some of the people being interviewed and their organizations. The utilisation of this information would have allowed for a more realistic and precise analysis of some of the cost factors and their uncertainty. This limitation would not have even been avoided by a lengthier interaction with the interviewees as suggested by McKinnon (1988, 41).

This study is divided into two sections. The first section constructs a theoretical background based on previous research and the later part focuses on the empirical analyses of the phenomenon under review.

The theoretical background for this research was obtained from two different areas of economic literature. The literature in question consisted of both books and scientific journals from both areas. The initial theoretical background was gathered from environmental economics literature and more specifically literature which are related to the theoretical justifications of applying environmental policies and as a result the different alternatives presented of allocating environmental damage costs. A more detailed description of the underlying theories of environmental policy based on liability is also provided, because this is the prevailing approach to allocating environmental costs generated by oil pollution.

Investment and risk analysis was chosen as the second part of theoretical background in order to benefit the internal analysis and future aspirations of Corporation X. It is the aim of Corporation X to promote a membership in their oil spill response system as an investment in the future on the part of their clients. Investment risk analysis is a suitable technique for this purpose, because most investment risk analyses are carried out for the benefit of upper level management (Bowers 1994, 12). This indicates that risk analysis techniques and their results are most used and best understood at a higher level of decision making. This benefits Corporation X, because it is their goal to raise awareness of environmental and especially oil pollution issues at the top management level of international oil companies. Awareness of these issues at that level can not be considered high at the moment. Risk analysis techniques are ideal methods for conceptualizing the visions of Corporation X in a way that is familiar and well understood by top level management.

In addition to fulfilling the objectives stated above, investment risk analysis methods also serve as a method of conceptualizing the uncertainty related this investment from the stand point of Corporation X. Even though investment risk analysis is normally utilised in investment decision situations for the evaluation of the uncertainty for example in net present value (NPV) of internal rate of return (IRR) calculations, these methods also seem appropriate for evaluating the overall uncertainty of this investment in other ways. The detailed evaluation of the uncertainty of critical variables, by using for example the dispersion in their historic values as a measure of their uncertainty provides a description of the overall uncertainty underlying in this aspect of the oil spill response investment.

The information, which forms the majority of the empirical part of this study, was gathered from three different sources: publicly available information sources, such as the internet, interviews and internal material of different organizations.

The empirical framework, which illustrates how total oil pollution costs are formed, was initially constructed based on information obtained from public information sources. This framework was then modified and specified based on the results obtained from the interview round. The interviews also provided qualitative information, which was utilised to complete the quantitative risk analysis. The majority of the data for the quantitative risk analysis was obtained from the information available in the International Oil Pollution Compensation Funds 2005 Annual Report.

A total number of six interviews were carried out for this study. All the interviews were conducted over a period of 26.6. – 3.7.2006 in England, at the respective offices of each interviewee. The lengths of the interviews ranged from one hour to approximately two hours. All the interviews, for the exemption of one, were recorded with the permission of the people being interviewed. The interview with the representative of P&I club X was not interviewed at his request. The interviews were recorded to ensure more effective analysis of the information obtained. The information from the interview which was not recorded was gathered by writing notes during the interview.

The chosen interview method defines the level of standardisation of the questions and the structure of the interview, i.e. how strictly the questions are defined in advance and to what extent the interviewer controls the interview session (Hirsjärvi & Hurme 1980, 42). The interview method chosen for this interview follows the description of a theme interview (Hirsjärvi & Hurme 1980, 50). A theme interview is a semi-structured interview form, where the primary themes and subjects of the interview are known, but the exact form and order of the questions is not defined. The objective is to focus the interview on specific themes, from which "deeper" information is revealed. This interview method was chosen for this study, because the basic themes, which needed to be covered in each interview, were known, but due to the lack of knowledge of each particular area from the part of the interviewer, it was crucial that the development of the interview was not restricted. This might have caused for crucial information to be left out. However, by limiting the conversation to defined subjects the length of the interview session was managed to be kept under control.

1.4 The Structure of the Thesis

This paper will continue by explaining the theoretical need and various alternatives of environmental policies, which govern the allocation of environmental damage related costs to polluters. A more detailed description of the environmental policy based on liability is presented after that, because this is the form of environmental policy applicable in oil spill situations. This will be followed by exploring the various investment risk analysis methods presented by related literature. The subjects of correlation between variables and information sources for risk analysis will also be explored. The empirical portion of this study will begin from chapter four. First, the different organizations related to oil pollution will be explained and the framework for evaluating oil pollution cost factors will be constructed. This will be followed by a risk analysis of the different oil pollution variables. The thesis will end with a discussion section, which in addition to highlighting the observations of this study will also include a section summarizing the basic restrictions of this study and suggestions for future research.

2 THE ALLOCATION OF ENVIRONMENTAL DAMAGE COSTS

2.1 Environmental Policy

From a social perspective the necessity for government activity in the environmental realm is derived from the fact that pollution is an externality, in the sense that it is an unintended consequence of market controlled decisions, affecting individuals other than the original decision maker (Stavins 2004, 1). The cost that has to be paid by these entities for the damage to other parties is the critical question in structuring the correct environmental policy. However, the entities emitting these harmful effluents usually do not directly bear the full cost of their behaviour, because these effluents are not usually traded in markets and are thus not priced. (Helfand et. al. 2003, 252) This creates the dilemma of correctly allocating costs of environmental damage.

Because of the nature of pollution being a publicly unwanted result of the production of public goods, a socially acceptable level of pollution has to found (Cropper & Oates 1992, 679). That socially optimum level of pollution can be obtained by utilising benefit-cost analysis, whereby the benefits of pollution control are compared to the respective costs. The aim is to maximize that difference and the level of environmental protection where this is reached is deemed the efficient level of protection. (Stavins 2004, 1) The foundation this assumption is that reliable estimates for social costs and benefits are available for an empirical benefit-cost analysis to be carried out (Stavins 2004, 2). From an individual's point of view the optimum level of pollution is determined by the benefits of the goods consumed by that individual and by the pollution that individual faces as a result of the production of those goods. The individually optimum level of pollution is reached when the marginal benefits of reduced pollution equal marginal abatement costs. (Cropper & Oates 1992, 678)

These optimum levels of pollution are not normally automatically reached since competitive firms with free access to environmental resources will engage in activities, which produce socially excessive levels of pollution. Assuming, that these emitting agents are at a disregard for the external costs imposed on other by the pollution they have caused. For this reason polluting agents need to be faced with a price equal to the marginal external costs of their polluting activities. This will result in companies internalizing the total social costs of their operations. (Cropper & Oates 1992, 679–680)

The social abatement costs in an environmental context can be defined as anything that has to be sacrificed to reduce or prevent the risk of environmental impact. Direct costs can include the costs for companies for purchasing and maintaining pollution abatement equipment or the costs for governments of implementing an environmental policy. However, if an environmental policy affects large portions of the economy, a more comprehensive general equilibrium analysis is needed to determine more indirect costs. The impact of environmental policy on existing taxes serves as an example of a situation when a more general cost analysis is required. (Stavins 2004, 3) Even though the costs of environmental policy range from direct to extremely indirect, their assessment and estimation can be considered more reliable and straightforward than the estimation of environmental benefits.

The difficulty in assessing the benefits of pollution control is due to the absence of prices for such scarce resource as clean air and water, which are resources affected by pollution. In the absence of market prices determining their value has to be done via other means (Cropper & Oates 1992, 675). The method usually adopted by economists is referred to as an anthropocentric point of view. This view deems that the environment does not have any value on its own, but its value is derived from its utility to human beings. (Zweifel & Tyran 1994, 44) The utility here refers for example to the possibility of people being able to breathe fresh air and swim in clean bodies of water. Different individuals appreciate these possibilities differently and thus environmental damages are best measured at the individual level. It is possible to use smog as an example. The cost of smog is higher for some people than for others, if they enjoy nature activities and clear sceneries. (Helfand et. al. 2003, 262)

The benefits derived from environmental protection can be categorised into three different types. These benefits can be related to human health, ecological impacts or material damages. The values of these benefits can be seen as use value and non-use value. Use value refers to the direct benefit received from the use of for example a natural resource. Non-use value is especially important in an ecological domain, because it can be derived from environmental quality. An example of a non-use value would be the value of Grand Canyon to someone who isn't planning to visit it but still values its existence. (Stavins 2004, 3) Defining a value for these damages is a process consisting of two steps. The first step is to assess a physical value to the damage and after that a monetary value is assigned to the damages. It is clear that assigning such monetary values is surrounded by great controversy, for example from the technical, political and ethical points of view. (Helfand et. al. 2003, 267)

The different methods of assigning values to environmental resources are divided into two categories. The division has been made between indirect market methods and direct questioning methods. (Cropper & Oates 1992, 700) Both of these methods will be addressed in the following section beginning with the indirect market methods. Indirect market methods rely on the choices made by individuals and their valuation can be done utilising three approaches. The averting behaviour approach is based on valuing certain purchased inputs which may decrease the effects of pollution. For example if a certain medicine can be taken to alleviate the health problems caused by smog. The usefulness of the averting behaviour approach is restricted to situations where the value of other inputs can be substituted for pollution. The weak complementarity approach utilises the complementarity of environmental quality to value changes in environmental quality. The value of increased demand for visits to a lake resort caused by an improvement in water quality can serve as an example. The third possible approach is the hedonic market method, which exploits the concept of hedonic prices. This refers to the possibility of breaking larger entities into smaller attributes and subsequently valuing those attributes. The price of a house is dependent on several different factors such as location, safety, services near by and also for example the quality of the air. The total amount someone would be willing to pay for that house is comprised by adding up the values of all these different factors. If an improvement in air quality would increase the value of housing in a certain area, than that increase in value would be attributable to the improvement in environmental quality. (Cropper & Oates 1992, 700–707) Even though indirect market methods have several benefits and these methods are feasible for evaluating the benefits of pollution reduction in many cases, there are still situations when these methods are not suitable. Indirect market methods are constrained to evaluating the before mentioned use values, but non-use values are an entire category which can not be measured with these methods. (Cropper & Oates 1992, 709)

Direct questioning methods can be utilised in situations in which the previously explained techniques are not suitable. Direct questioning methods rely on estimating an individual's willingness to pay (WTP) for the prevention of an environmental damage or an individual's willingness to accept (WTA) compensation to tolerate environmental damage (Stavins 2004, 3). The method usually utilised to obtain these figures is called contingent valuation (CV). This technique is more popularly used to obtain an individual's WTP, but it can also be used for obtaining a WTA value. In this method respondents are presented with a tradeoff scenario; something in exchange for an environmental good or service. In this way an individual's WTP is obtained. This method can also be carried out in the form of a bidding game, where first a WTP or WTA figure is presented and a response of yes or no is given. This figure is then increased or decreased until indifference is achieved. The latter questioning technique, referred to as close-ended questions, have been generally deemed easier to answer and thus provide more reliable answers than open-ended questions. (Cropper & Oates 1992, 710)

The CV method was widely used after the Exxon Valdez oil spill accident to obtain a numerical value for the environmental damages caused by the oil. The most significant advantage of CV is that it possible to adapt it to numerous different situations. However, answers may suffer from great variance and bias if no budget constraint is applied to the answers. This is especially a challenge in open-ended questions, because respondents might not have an anchor point to which they can base their answers on. However, this problem seems to be less of an issue when the value of a private good is in questions compared decision situations involving public goods. (Cropper & Oates 1992, 711) Respondents may also aim for higher personal satisfaction, which is derived from wanting to preserve the environment, by stating a high, but unreal WTP figure. (Stavins 2004, 7–8) For these reasons, the problems arising from the way a particular survey is carried out have to be taken into consideration and that is why these methods can be considered to provide crude estimates. (Fisher & Peterson 1976, 21)

A socially optimum level of pollution can be found somewhere between zero pollution and the pollution caused by unregulated activities. This is due to the fact that zero pollution is not a feasible option from the physical process point of view and as already mentioned, unrestricted pollution causes damages, which can not be ignored by the entities generating the pollution. (Helfand et. al. 2003, 267) Identifying this socially optimum level of pollution and setting up the appropriate means of how this goal can be achieved is the role of regulators and the means of how this can be achieved is by an appropriate environmental policy (Stavins 2003, 358). The need for either a legal or other regulatory system in the environmental context is derived from the socially inefficient results of companies operating in an unrestricted state (Helfand et. al. 2003, 254).

As stated above, the underlying theory behind the need for environmental regulation is that it is more efficient for companies to pollute than not to pollute and therefore legal requirements are required to control the level of pollution. However, sometime companies adopt policies, which exceed their requirements for environmental operation. The possibility of upholding environmental control via such voluntary programs is discussed in Helfand et. al. (2003, 295–296). A reason why companies adopt such practices is that pollution may indicate the ineffectiveness of their operations and they are not reaching their greatest possible output. By reducing the level of pollution, the utilisation rate of their input products is raised. Other reasons for such behaviour include the possibility of benefiting from a more environmentally friendly image, voluntary programs may avoid regulators imposing more costly mandatory controls and finally, a company may benefit from the technological advantage of an early innovator if the voluntary policy becomes a requirement in the future. The prevalence of companies adopting voluntary environmental programs has received increased attention, but the empirical studies have generated mixed results about the possibilities of obtaining a “win-win” situation.

Even though the possibilities of voluntary programs have been raised in recent times, not all polluters will consistently reduce their effluent levels without mandatory regulation (Helfand 2003, 296). There exist several options of legal and other regulatory systems for controlling the emission of effluents. It is possible to categorize the different methods from two alternative viewpoints. The first categorization can be made by dividing these methods into ex ante and ex post measures. Ex ante measures are effective before any damage has occurred and ex post measures are only effective once an accident has already taken place. (Zweifel & Tyran 1994, 51)

The second type of categorization can be made between command-and-control and market-based methods. Traditional methods are referred to as command-and-control methods, because they allow relatively little flexibility in the means of achieving set goals. They force companies to take on equal shares of the pollution control-burden, regardless of the cost. (Stavins 2004, 9) This is done by setting uniform standards, which usually are either technology or performance based standards. Technology based targets stipulate the actual method mandatory for achieving a target, while performance standards set a uniform control target but allows for latitude in how these targets are met. (Stavins 2003, 358) There are some serious downfalls associated with these methods, the most serious of which is the unduly costs experienced by some parties. This is due to the fact that, for example given technology may be appropriate for certain companies, but inappropriate for others. Thus control costs can vary significantly between different companies and even within the operations of a single company. (Stavins 2003, 358–359) In other words, in the real world scenario of companies being heterogeneous, command-and-control methods can not provide a cost effective solution. However, if these costs are at similar levels between sources, the command-and-control methods may prove to be effective methods of regulation.

As mentioned, the individual characteristics of different industries and even different companies operating in the same industry cause for the command and control methods to achieve cost-ineffective results. If the basic assumption of assigning the same standard for example for all companies within a given industry is relaxed and the standards are individuated, more cost effective solutions can be reached. An example of adopting varying standards in different conditions is applying alternate taxes to oil pollution emitters according to their location in relation to dense population. The increased efficiency will however have to be balanced with increased administrative costs. (Fisher & Peterson 1976, 13) A significant portion of these increased costs would be due to the increased amount of knowledge and the processes required for gathering that information on the part of the regulator (Helfand et. al. 2003, 277). In addition to the rise in costs, such adaptive measure may be constrained by the fact that required information is simply not available. For the most part regulators are forced to make decisions with out exact knowledge of the costs and benefits of the chosen environmental policy. In addition to the imperfect information concerning benefits and costs, the inability in some situations to pinpoint pollution to a specific source affects environmental regulation decisions. (Helfand et. al. 2003, 287–288)

Opposed to command-and-control methods, there exists the alternative of market based instruments. They are developed to encourage company behaviour through market signals, rather than through explicit regulations concerning pollution control methods or levels. These instruments provide incentives for the greatest reductions in pollution to companies, which can achieve it with the lowest costs and they also provide incentives to adopt cheaper and better-pollution control technologies, thus driving down abatement costs. Market-based instruments can be divided into four separate categories: pollution charges, tradable permits, market-friction reductions and government subsidy reductions. (Stavins 2004, 9) A short description of these methods will be given in the following. (Stavins 2003, 360–361)

Pollution charge systems are based on imposing a tax or fee on the amount of pollution generated by a given company or source. The difficulty in this method is assessing the correct level of tax or fee. In an ideal case, the tax level should be set equal to the marginal benefits of clean-up at the efficient level of clean-up. However, policy makers tend to make decisions according to the desired level of clean-up.

In a *tradable permit* system, an allowable overall pollution level is established and then allocated to individual companies in the form of permits. If a company manages to keep their pollution level lower than their allowed level, they are entitled to sell their excess permits to other companies or use them to offset excess pollution in other parts of their facilities. This system achieves the same cost minimizing allocation of the control burden as the above pollution charge system, with out the problem of uncertain responses by companies.

Market-friction reductions provide gains in environmental protection by reducing existing frictions in market activity and they can be divided into three alternate methods. Firstly, market creation for inputs and outputs associated with environmental quality. Secondly, liability rules that force companies to consider the environmental consequences of their decisions and finally, information programs that are directed at promoting environmentally friendly alternatives for example by ways of product labelling and reporting requirements.

Government subsidy reductions are based on the concept of subsidies being the mirror images of taxes. Thus altering the level of subsidies allocated by governments according to a company's operations may provide incentives for them to consider environmental factors. However, practical applications have actually in many situations promoted inefficient and environmentally unsound practices.

In the context of oil pollution, allocating the costs generated by oil pollution is set up according to a liability policy, which is a sub-category of the market-friction reduction methods presented above. A liability policy in allocating environmental costs has not received as much attention in literature as other market based instruments. Considerably more focus has been given to the pros and cons of for example tradable permits and pollution charges. The next section will describe the various aspects of a liability driven system and its various aspects, which are meaningful in a general environmental and more specifically in an oil pollution context.

2.2 Environmental Damage Liability

An environmental policy based on a liability rule is founded on the notion that a company retains the right to carry out potentially polluting activities, but if this pollution results in social damage, it is liable for paying compensation to cover those damages. The compensation amount is determined by a third party. (Larson 1996, 33) The right to make environmental liability claims is reserved to parties that have suffered from unauthorized environmental pollution (Zweifel & Tyran 1994, 45). Liability rules can be a cost effective policy, because the technologies or practices for achieving the requirements are not specified (Stavins 2003, 410). The regulators simply rely on the liability rule to discipline possible polluters (Cropper & Oates 1992, 693).

Environmental policy based on liability has a triple function (Zweifel & Tyran 1994, 43):

1. Compensation
2. Internalization
3. Prevention

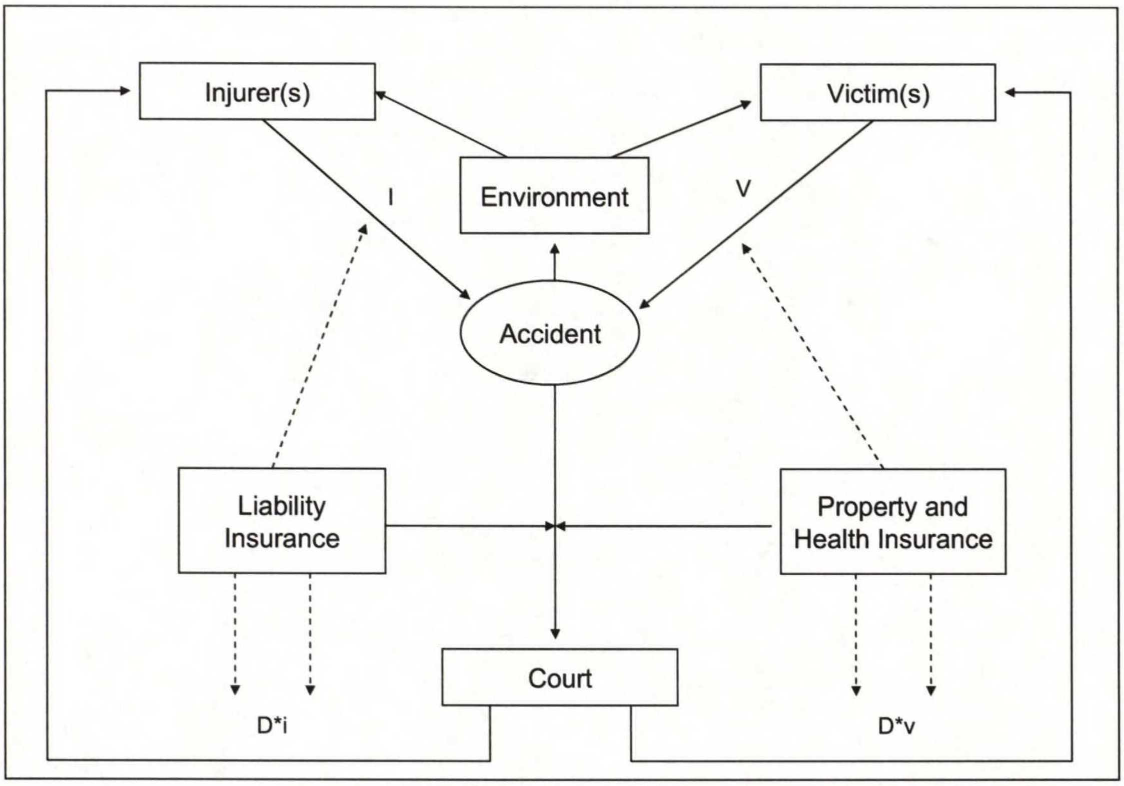
Making a polluter liable for environmental impairments secures compensation for possible future victims (Zweifel & Tyran 1994, 43). The aspect of securing compensation for victims is an aspect, which is unique to environmental liability. The function of internalization operates in two ways. Firstly, a liability rule provides an incentive for companies to adopt a process of consideration of environmental impacts into the internal decision processes of company (Stavins 2003, 410). If no such policy existed, then companies would have no incentive to internalize the possibility of damage into its decision calculus (Larson 1996, 35). The second aspect of internalization is that the damage costs are assigned to the liable party. Liability encourages prevention, because by adopting the appropriate levels of prevention and risk reduction, companies can diminish or totally avoid future environmental damage costs.

The internal decisions concerning the methods of operations in a company can have an effect on the level of environmental damages affecting the future wealth of the company (Larson 1996, 41). However, there is a lag between the point when decisions concerning environmental safety are made and the payment of possible compensations (Larson 1996, 34). This adds the element of uncertainty, because the impact of these decisions on decreasing possible liability payments in the future and their potential impact on total company wealth are open to speculation. However, because an environmental policy based on liability allows for freedom in the methods adopted to avoid environmental damage, there is a connection between the environmentally focused decisions made by the company and the future economic consequences of those decisions.

It is possible to distinguish three different levels of liability. Comparative negligence holds an injurer liable if he failed to take a minimum amount of prevention. Strict liability always holds an injurer liable. The level of prevention taken on the part of the injurer is insignificant in strict liability situations, if the victim has taken due care. Absolute liability applies when the level of prevention taken by the injurer and victim are unimportant. (Zweifel & Tyran 1994, 45) The liability rule in the context of oil pollution situations is a form of strict liability, because as later will be illustrated, the polluters liability can not be removed depending on the level of prevention taken by them.

The key actors in a liability situation are the injurer, the one causing the damage, the victim who suffers from the damage and a third party, often a court which deems the appropriate amount of compensation. The relationship between these actors in a simple liability situation is presented in figure 1. The principles of a liability situation in a general context will be presented first and after that the special characteristics applying to environmental and oil pollution liability situations will be discussed.

Figure 1. The relationship between injurer, victim and court in a simplified liability situation.



D	= monetary value of damage
i	= share of damage to be paid by the injurer
v	= share of damage to be paid by the victim
I	= amount of hazaroduous activity by the injurer
V	= amount of hazardous activity by the victim
→	= influences emanating from primary actors
---→	= influences emanating from insurers

Source: Adapted Zweifel & Tyran 1994, 45

The injurer has a choice between risky activity (I) and less risky activity. In some instances also the victim can control the amount of risky activity (V) it performs. An example of this is driving a car, which can be assumed to contain some elements of risk and by reducing the amount driven; a person is able to control the amount of risky activity. In environmental pollution instances this does not hold true, because victims usually do not have an influence on the probability of an accident (Zweifel & Tyran 1994, 46). In some pollution instances it is possible for victims to some degree avoid exposure, for example by installing a water purifier (Helfand et. al. 2003, 266). Yet clearly in the context of oil pollution, an individual's ability to avoid the damages it generates can be considered non-existent.

If an accident occurred, the victim has to decide whether to sue the injurer. This decision will depend on the amount of damage, the injurer's ability to pay for the damages and on litigation costs. Because of the potential magnitude of damages generated by environmental pollution, it is possible for them to exceed the assets of the injurer and thus making the injurer exposed to bankruptcy. This might result in the victims being left with out compensation. The gap between the funds available by the injurer and the amount of damages can be closed by specific environmental impairment insurance. (Zweifel & Tyran 1994, 49) The existence of insurance would thus result in increased efficiency of the liability rule. Lack of efficiency being one of the aspects most criticised about this type of environmental policy. (Zweifel & Tyran 1994, 43) However, the financial cover provided by insurance may result in the injurer's decreased interest in prevention and courts following a so called "deep-pocket" policy, resulting in higher compensation amounts due to the increased ability to pay provided by the injurer's insurance cover. The existence of insurance also provides a moral hazard for the victims, because they may be encouraged to attempt to gain personal economic benefit on completely unfounded or inflated damage claims. (Zweifel & Tyran 1994, 49)

The oil pollution liability policy has taken into account the aspect of introducing additional environmental insurance. Significant efficiency gains of oil pollution liability compensation payments have been obtained by putting into effect a system of compulsory insurance. The requirement of compulsory insurance has made it possible for those organizations that govern the liability payments related to oil pollution to operate in an effective manor and the payment rate for damages has remained high. Oil pollution damage claims are assessed by an independent party, by assessing the technical merits of each individual claim. This procedure resolves to some extent the problem of compensations paid to unfounded claims and the compensation amounts remaining at the appropriate level compared with the actual damage.

A distinctive feature of environmental pollution situations is that there are often one or few injurers, but a multitude of victims. This makes the task of allocating both liability and appropriate compensation amounts between the injurers and the victims more challenging and the role of jurisdiction in determining these amounts is enhanced. (Zweifel & Tyran 1994, 47) Pinpointing the liable party in oil pollution situations can be done with great accuracy. This also results in increased effectiveness of the liability rule as an environmental policy in the oil pollution context. The usually straight forward process of determining both oil pollution injurer and victims also increases the incentive of the potential injurer to take adequate measures of prevention. The effectiveness of the liability rule has been suggested to decrease caused by the fact that there is sometimes the possibility that the injurer will not be sued (Shavell 1984, 271).

3 RISK ANALYSIS

On important aspect in understanding and managing investment related risks, is the fact that risk creates competitive advantage opportunities. In the absence of risk, rational decision could always be made with out taking into consideration the effects of complexity and uncertainty and thus the possibility of companies obtaining competitive advantage would be lost (Ståhle et. al. 2002, 181). Two states of expectation are possible regarding the future profits and costs of an investment opportunity: certainty and risk (uncertainty). Certainty can be strictly defined as single-valued expectations. In a more loose description certainty can also exist in situations, when these expectations are bound within a very narrow range (Levy & Sarnat 1990, 189). Although the terms uncertainty and risk are often used interchangeably, it is possible and necessary to make a difference between them. Risk deals with situations where the different possible events of the future are known along with their possibilities of occurrence (Aho 1982, 162). Also the element of correctly identifying the relationships between the various occurrences can be added to the definition (Ståhle et. al. 2002, 181). In comparison, uncertainty refers to situations when the possibilities of occurrence of each respective outcome are not known (Aho 1982, 162). In other words risk is uncertainty with known probabilities.

To build upon defining the concepts of risk and uncertainty, it is possible to define the concept of risk analysis. Risk analysis is a broad tool to approach the challenges created by uncertainty. This may include the identification, evaluation, control and management of risk. (Cooper & Chapman 1987, 2) This study will focus on the methods available for the identification and evaluation of risk.

In order to utilise investment appraisal techniques, which are based on the evaluation of investment generated cash flows, the size of these cash flows must naturally first be estimated. These estimates are often constructed based on estimates of other variables. For example, when evaluating investment profitability, market share and the expected price of the sold product have to be first estimated. This example demonstrates, that in reality the uncertainty involved in investment projects arises from the uncertainty of these "primary" variables, which then in turn is passed on to the calculated performance measures. (Hull, 1980, 16)

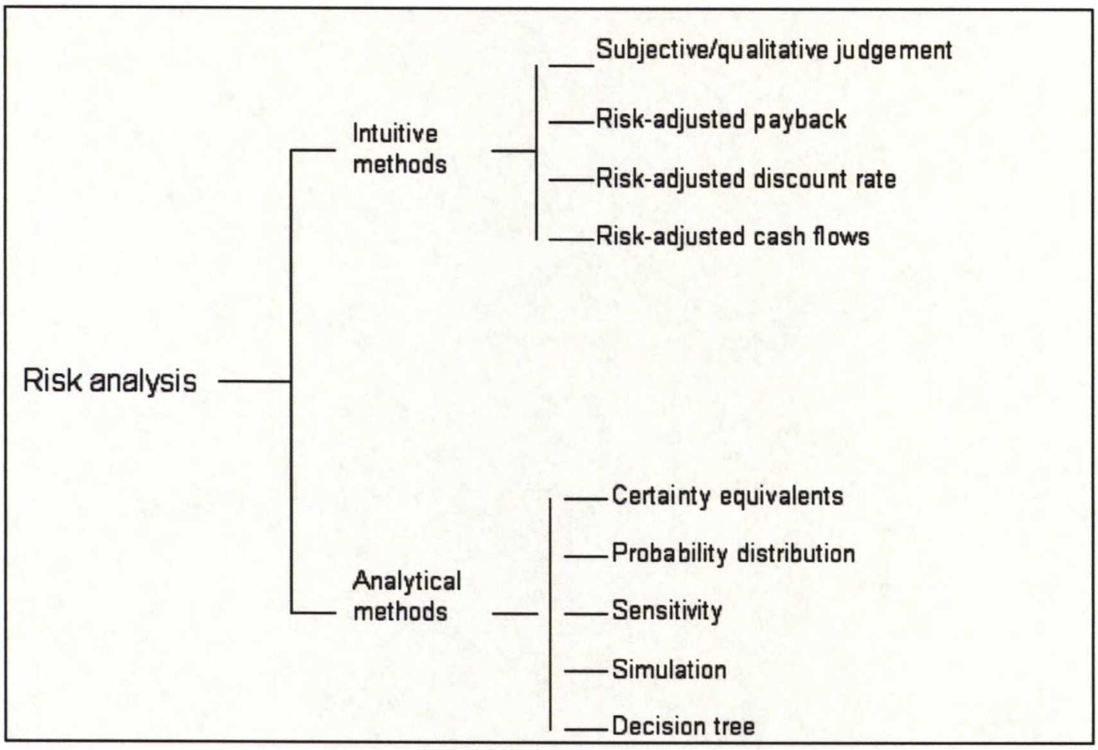
Thus, in order to estimate the uncertainty in a given investment, the factors affecting the investment cash flows must first be discovered. Only after the identification of these variables and the estimation of their uncertainty, is it feasible to make estimations on the effects of these variables on the investment calculations. These kinds of more complicated situations are becoming more and more frequent in the present economic environment (Shapiro 2005, 109). The importance of being able to understand the different sources of uncertainty and their influence on the value of a given project is growing (Shapiro 2005, 110). The usefulness of project risk evaluation depends on the ability to identify the nature of uncertainty in key project variables and having the knowledge and tools to process the implications of these risks (Savvides 1994, 1).

The techniques and methods referred to as risk analysis are critical to capital budgeting, because of the almost unavoidable dimension of uncertainty involved in those decisions (Smith 1994, 20). In the relevant literature these methods and techniques are usually divided into two categories. Pike and Ho (1991) make the division into simple risk-adjustment (SRA) techniques and probabilistic risk analysis (PRA) techniques. Smith (1994) separates between intuitive and analytical techniques. The substance in both is virtually the same, but in this study I will follow the guidelines presented by Smith (1994, 20).

Intuitive techniques are not based on the exact description of uncertain factors in investment cash flows. They can be described more as subjective estimates, which prepare for the discrepancy between the actual and predicted values of cash flows. Risk-adjusted discount rate and risk-adjusted payback period are examples of intuitive techniques. A combining factor for the intuitive risk analysis methods is that they are all based on single value estimates. A single value estimate can depending on the situation refer to the mode, the average or a conservative estimate. The uncertainty factor is then incorporated into these estimates by varying methods, such as with a higher discount rate or by shortening the payback period. In using intuitive methods one does not obtain an explicit measure of the risk of the investment (Hillier 1963, 444).

As almost an opposite, analytical techniques rely on the exact definition of investment uncertainty. Simulation, sensitivity- and decision tree analysis are examples of these techniques. Analytical methods take into consideration investment uncertainty by evaluating the distribution or variation of values in the investment calculations (Savvides 2004, 4).

Figure 2. Risk analysis techniques divided into intuitive and analytical methods.



Source: Smith, 1994, 20

Narrower approaches to the different available methods of risk analysis are also presented in literature. Examples of these include the research of Aho (1982) and Savvides (2004). Aho divides risk analysis techniques also into two groups. However, the basis for division is very different from the one previously explained. His division consists of two groups labeled analytical and simulation techniques. In Aho's definition, analytical methods can be used to estimate risk by interpreting statistical characteristics of the profitability distribution. According to Aho, these methods are only feasible in simple investment situations, consisting only of one uncertain variable. The simulation technique presented by Aho consists only of simulation analysis, where a profitability distribution is created as a result of numerous computer runs. An even narrower classification is the one of Savvides (2004), where risk analysis as a whole is used to refer only to simulation analysis. These classifications of risk analysis techniques are more constricted, because they do not recognize the various existing risk-adjusted techniques as being risk analysis techniques at all. Nor have sensitivity and decision tree analysis been classified to any group.

In this study I will focus on the analytical techniques of risk analysis outlined by Smith (1994). The reason for this is simple. One of the main objectives of this study is to define the uncertain cost factors related to oil pollution in the most precise manner possible. This can be achieved by evaluating the value distributions of relevant factors. Intuitive methods seem to provide a straightforward solution for incorporating the uncertainty of key variables (Cooper & Chapman 1987, 13) however; the use of intuitive methods would not provide any indication of the degree of risk in the costs being evaluated. By following the guidelines provided by analytical risk analysis methods, it is possible to define the individual uncertain variables, the level of their individual uncertainty and their effect on the value of the dependent variable.

Analytical risk analysis can be approached using a simple three step method. The first step is to specify the base variables, which define the value of the dependent variable of interest. Secondly, specify the relationships between the base variables and finally, calculate the value of the dependent variable. The underlying assumption behind this process is that it is more accurate to define the base variables first, instead of attempting to define the derived variable directly. This is particularly important if the tail areas of the value distributions are of interest. This is because the low probability high consequence events represented by the tails may prove crucial for decision making, despite the fact that they may contribute very little to the expected value. (Cooper & Chapman 1987, 12) The effect of these critical tail values would thus be missed if single value based techniques were utilised.

From the group of analytical risk analysis methods, this study will focus sensitivity analysis and simulation. As the following sections will illustrate, these techniques are closely related to each other and they aid the decision maker in visualizing the outcome and probabilities related to a particular decision (Hassan et. al. 1978, 43). Clearly defining the possible outcomes and their respective probabilities is especially important in the present situation, because this subject is at this point relatively unfamiliar to the ultimate decision maker.

Although it seems rational to state that increased knowledge of project inherent risks lead to better decision outcomes (Pike & Ho 1991, 236), independent of the choice of risk analysis technique, or even the decision to carry out risk analysis, the successfulness of the ultimate decision can not be guaranteed. The results of the study of Farragher et. al. (2001) showed no association between the use of formal risk analysis and improved company performance. Future events may change and what seems like the best of decisions today into a poor one tomorrow. Risk analysis can only point out the greatest risks and perhaps how these risks may be avoided. (Hassan et al. 1978, 43–44)

3.1 Sensitivity Analysis

With the use of sensitivity analysis, it is possible to analyze the effect on investment profitability if one or more uncertain variables deviate from the value used in investment appraisal calculations (Aho 1982, 164). In sensitivity analysis the value of one variable is changed at a time and the all the other variables remain at their expected values (Cooper & Chapman 1987, 14). This will then enable to determine the effect of change in this one variable has on the total value of an investment. In other words, sensitivity analysis is applied to the individual factors rather than to the project as a whole (Hirst 1988, 108).

The use of sensitivity analysis is optimal for solving "what if" questions raised by top management or the individual departments involved (Shapiro 2005, 119). These questions can be answered by observing the effect of change in input variables within that particular model (Jovanović 1999, 218). The ability of transforming static decision models into comparative decision models is critical in the utilization of sensitivity analysis (Hassan et. al. 1978, 45). Because all comparisons are made within the context of the sensitivity analysis model appropriate for that particular situation, great emphasis must be put on the correct construction of the model. A suitable model should be a simplification of reality, still including the operative elements of that situation, but disregarding irrelevant noise (Hassan et. al. 1978, 43).

In addition to revealing the effects on output variables caused by the uncertainty of an input variable, sensitivity analysis can also be utilized to aid in pre-emptive planning. Based on the results of sensitivity analysis, it is possible to plan necessary steps and actions to purposely have an influence on the effects an input variable may have (Jovanović 1999, 219). This is a more proactive manor of sensitivity analysis utilization. It allows for the organization to gain insight on the most critical aspects of a situation and especially the ones, which can be influenced with its own measures. By directing resources, the level of uncertainty can be further decreased.

The above perspective on the use of sensitivity analysis is crucial to this study. In addition to providing Corporation X with an insight on the different variables affecting total oil pollution costs, the results of this study will provide a basis for evaluation to what extent the oil spill response concept can have an affect on these variables. This evaluation will be critical in approaching oil companies and presenting the financial benefits of the new model.

In order to use sensitivity analysis, some information about the probability distribution of the variables must be obtained in advance. These probability distribution estimates might be based on historic facts or subjective judgments. (Hirst 1988, 109) A detailed description on the pros and cons of both sources of information will be provided in chapter 3.4. The outline of the probability distribution does not have to be complete. Only a few input values are needed, for example a pessimistic, most likely and optimistic estimation for the variables is sufficient (Shapiro 2005, 119). It is a rather straight forward process to extract this information from historical data, but if the estimates are based on subjective judgments, it is a requirement, despite the challenges involved, that the input values are expressed in quantifiable form (Hirst 1988, 108).

When sensitivity analysis is based on subjective judgment, the result does not only reveal how sensitive the project overall return is to the variability of the relevant factors, but it also demonstrates how sensitive project returns are to the different assumptions made concerning the variables (Shapiro 2005, 119). It can reveal if the underlying assumptions were either too optimistic or pessimistic (Hillier 1963, 444) and provide information about the investment risk if changes in the underlying assumptions are made (Borgonovo & Peccati 2004, 18).

The major shortfall of sensitivity analysis derives from its basic form. The use of this technique may reveal if the project is sensitive to a change in one or a few key variables, but it does not take into account the probability of such a change occurring. Results indicating the significance of a certain variable may be rather useless if the probability of a change occurring is limited. (Shapiro 2005, 126) The uniform application of sensitivity analysis on all project variables may produce restricted results, since the probability of a 10% change occurring in for example labour costs is higher than the probability of a same size relevant change in sales revenue (Savvides 2004, 5).

Another major restriction on the applicability of sensitivity analysis is the fact that it does not take into account the possibility of simultaneous change in several variables (Shapiro 2005, 126). Sensitivity analysis also doesn't allow for possible dependencies between variables to be taken into account, because when the value of one variable is altered, all other variables are assumed to remain at their expected levels. Resulting from these two shortages, the possibility of drawing conclusions about total investment risk based on sensitivity analysis alone is restricted (Hull 1977, 202). The usefulness of sensitivity analysis is limited to providing information concerning individual variables only and as such it is not a method for total risk evaluation, but more so of risk description.

Despite the limitations related to sensitivity analysis, it should still always be carried out before attempting simulation, in order to identify the relevance of each factor and leave out the least contributing factors from the simulation. (Hull, 1980, 30) After identifying the variables, which have the highest contribution to the overall risk of the project, the obtained information can be used so that the project is modified so that some of the more significant risks are avoided or that more research is done on the most risky factors, to enable more accurate forecasts to be made. (Hirst, 1988, 108) Another reason for incorporating only the most crucial variable into the simulation is that as the number of incorporated variables grows so does the probability of creating unrealistic scenarios. This is caused by the difficulty in defining and monitoring the relationships of correlated variables. (Savvides 2004, 5) The challenges of correlated variables will be addressed in more detail later.

3.2 Simulation

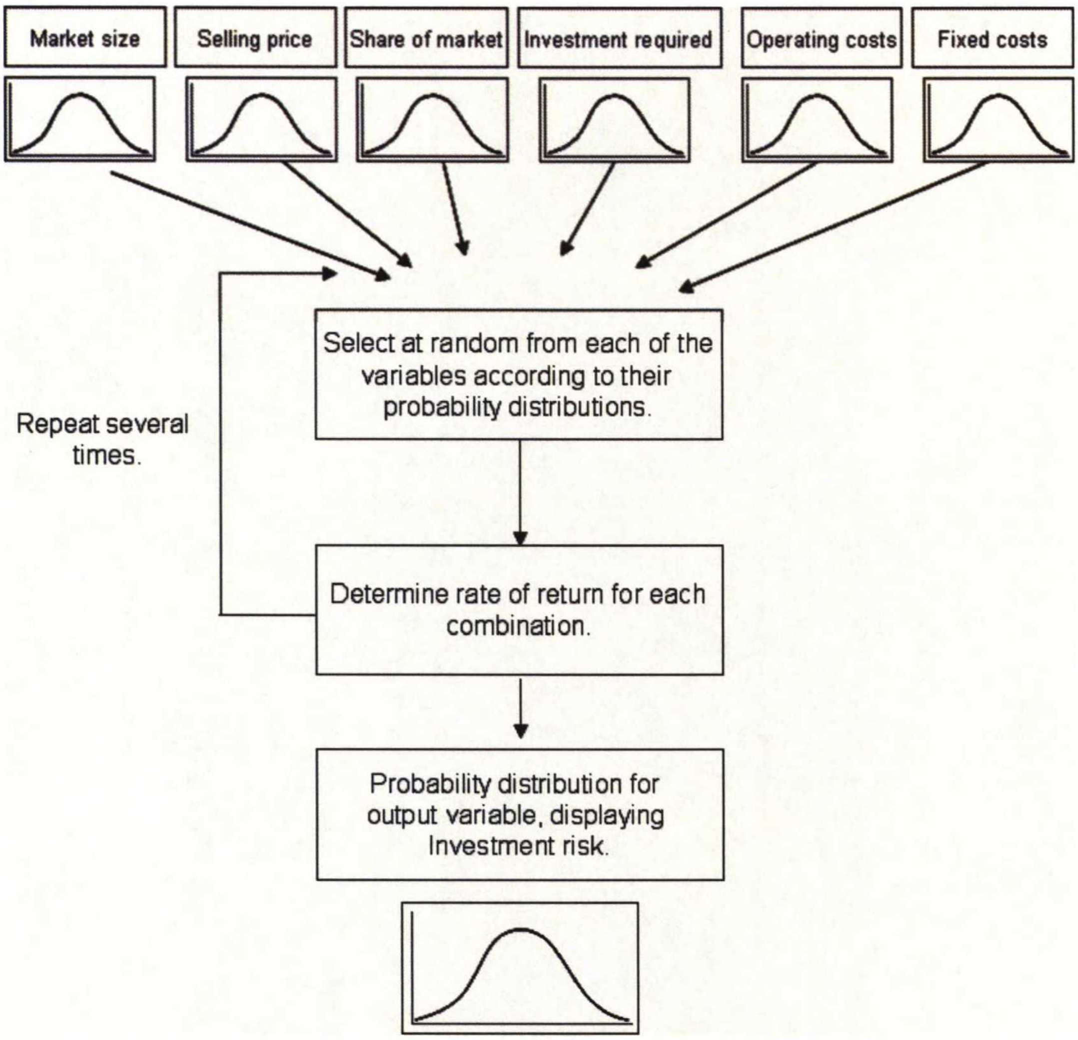
The major shortfalls of sensitivity analysis can be corrected by carrying out a simulation analysis. Simulation analysis can be described as bringing sensitivity analysis to its logical conclusion by adding a dynamic dimension. The construction of a simulation model makes it possible for random scenarios of investment profitability to be built, which are consistent with the original assumptions concerning project risk. (Savvides 2004, 3)

When talking about simulation in the context of risk analysis, one is usually referring to a technique called Monte Carlo simulation (Smith, 1994, 20). Hertz (1964) was one of the first to study the possibility of using simulation as a way of improving management estimates of investment profitability. In his view, the discounted cash flow appraisal techniques used were mathematically sufficient, but the problems were caused by the estimates used for these calculations. The estimates he was referring to were usually the same as the most likely estimate for a variable. This meant that distribution of values on either side of the estimated value was ignored. To aid in the more accurate estimation of project uncertainty, Hertz found it useful to base his calculations on these value distributions of the different factors, instead of single best estimate values. Investment uncertainty would thus be mapped out in the dispersion of values of each individual variable.

Hertz (1964, 101) concluded that simulation analysis was superior to single value based methods of project return evaluation, because more confidence can be based on correctly estimating a distribution of values than a single most likely value. Simulation analysis also improves decision making, due to the simple fact that decisions bases on the results of simulation analysis are utilising a bigger portion of the available information.
Hertz (1964, 99) described the construction of a Monte Carlo simulation as a three step process. The first step is to determine the critical variables of the decision and then estimate the range of values for each variable and the likelihood of occurrence for each respective

value. After this, one sample from each value distribution should be selected at random and the rate of return calculated for that combination. A sample can be considered random if all the range of possible values is eligible for selection and the probability of a value being selected is defined by the probability distribution of the variable (Hull 1980, 28). As the final step, this process should be carried out repeatedly until a probability distribution for the rate of return of the investment is obtained.

Figure 3. The basic construction of a Monte Carlo simulation model.



Source: Adapted from Hertz 1964, 102.

The major benefit of estimating project risk with simulation analysis is that the model can virtually without restrictions be developed as complicated as necessary to ensure that all relevant information of all relevant variables is included (Hull 1980, 32). However, this benefit is reflected on higher information requirements. The construction of a simulation model requires three types of information to be available. The certainty equivalent estimates, the distribution parameters around these estimates and the correlation between the incorporated variables must be known (Aho 1980, 182–183). In addition to these, naturally the variables of interest have to be known, but as was stated in the previous section, if a sensitivity analysis has been carried out before simulation, the number of variables, which need to be incorporated into the simulation model, can be decreased.

If compared to the information requirements of sensitivity analysis, the information requirements are higher, because the shape of the distribution of values for each variable is needed. On a variable for variable basis, it has to be assessed if the values of the variable are for example normally distributed or if the distribution takes another shape (Hirst, 1988, 121). The probability distributions for some variables included in typical projects, such as initial investment and productions costs can be estimated with higher confidence level than for other variables, such as price and market share (Shapiro 2005, 126). As was previously described in sensitivity analysis only an estimate of the upper and lower bounds together with the expected value for a variable was sufficient.

There are two ways of obtaining the required value distributions. The first option is to utilise historic data and the second is to estimate the distributions based on subjective estimates. It is clear that both of these options have their individual benefits and challenges, this is why this subject will be discussed in detail in chapter 3.4.

The second challenge for obtaining realistic simulation results is derived from the possibility of correlated variables. The simplistic model described earlier is appropriate if it assumed that all the variables are independent from each other, i.e. the value of a variable is not influenced by the value of another variable. The correlation between variables is an important concept and its assessment and if necessary incorporation into the constructed simulation model is critical in obtaining realistic simulation results. (Savvides 2004, 13) The various methods presented by literature for incorporating correlation between variables into a simulation model are discussed in more detail in the following chapter.

A simulation model provides a more complete picture of investment related risk. Whereas sensitivity analysis only described the risk involved in individual investment variables, the results of a simulation analysis provide a complete illustration of total project risk. Because the results from a simulation analysis are presented in the form of a probability distribution, an array of statistical ratios for an investment can be calculated such as the mean, minimum and maximum values, in addition to the standard deviation and skewness coefficient. Also important pieces of information are the percentile probabilities of the probability distribution. With the aid of these it is easy to evaluate the probability that the investment will be under or over a certain value. (Pellonmaa 2006, 42) For example the probability that the project will break-even is easy to obtain from such an illustration.

However, despite the benefits of obtaining an investment probability distribution, a simulation analysis does not provide a clear-cut answer to whether the project should be accepted or rejected, as would be the case in risk adjusted cash flow methods based on single values, which provide the decision maker a prepared decision embedded in the results. (Shapiro 2005, 128) Because of this, the decision has to be made according to decision maker's or in some cases to whole organization's attitude toward risk. The probability of an investment having an X % probability of breaking even might be acceptable for some, but unacceptable for others.

3.3 Dependencies between Variables

As mentioned before one of the major advantages of simulation analysis is, that the model used can be developed as complicated as required. The detail level of a model can be referred to as its level of disaggregation. A higher level of disaggregation increases the realness of the model, but as a trade of, it also creates problems. The most critical of them is the problem of dealing with interdependencies. (Hull 1980, 61–62) Interdependencies can occur between the values of two or more different variables or between values of the same variable during different time periods.

Two variables in an investment decision are dependant of each other, if a change in value of one variable causes a change in value for the other variable (Hull 1980, 57). The more a simulation model becomes realistic, the more there can be assumed to be dependencies between different variables within the same time period. A classic example of this is the dependency between demand and price. Usually in times of strong demand, higher prices also prevail. A similar relationship can be seen in the reverse situation involving low demand and low prices. (Shapiro 2005, 127)

Interdependency between time periods can be demonstrated with an example using costs. If costs would change independently from one period to the next, there would be no dependency to take into account. However, this is not a realistic assumption. If costs decrease in one period to a level which was not expected, this will also imply lower costs in the following time periods. (Shapiro 2005, 127)

Dependencies in risk simulation are problematic, because their existence will infer with obtaining the correct result from independently sampling from the probability distributions of different variables (Hull 1980, 57). Dependencies can be classified depending on how important they are in determining the outcome of the simulation. It is beneficial to separate the most important dependencies so, that several irrelevant assessments to the decision under consideration do not have to be made. The importance of a dependency can be estimated by comparing the distribution of the calculated performance measure assuming no dependency and the same distribution assuming total dependency. If the difference in distributions is very little, then the effect of dependency can be assumed to be unimportant and no additional analysis of the nature of the dependency is needed. Further research would be justified if the discrepancy in distributions could be considered noticeable. (Hull 1980, 60)

Specifying and especially incorporating interdependencies into a simulation model may be challenging (Shapiro 2005, 127). The easiest answer for dealing with dependencies between variables would be to assume either no dependence or total (positive or negative) dependence (Hull 1977, 202). Total dependence in this case means that if variables are totally positively dependent, then when variable *x* receives a value from fractile *k* of its probability distribution, then *y* receives a corresponding value from its probability distribution. If the variables are totally negatively dependent, then when receives a value from fractile *k* of its probability distribution, then y receives a value from the (1-*k*) fractile. The main benefit of defining total dependence in this form is that now samplings from variables with varying probability distribution forms are feasible. This allows for a totally dependent sampling of variables which have for example triangular and normal probability distributions. (Hull 1977, 203) Assuming no dependence between variables is naturally the simplest alternative. No dependence refers to the state when a change in the value of variable *x* does not have an affect in the value of variable *y*.

Often in real life imitating simulations, choosing between total and no dependence does not convey the characteristics of the variables. The need for methods, which incorporate different levels of dependencies, is clear. The construction of these methods and their applicability into the corporate environment has proven to be challenging.

In the study carried out by Kryzanowski et. al. (1972, 43–44) the problems of incorporating dependencies between variables into a simulation model, which was based on subjective estimates, was clearly highlighted. The biggest hurdle was undoubtedly the difficulty in clearly expressing the varying degrees of dependency. As a result a simplistic approach of assuming slight, moderate or high degrees of dependency was applied. However, defining these terms in a uniform manner may prove to be challenging. In addition to the fact, that these terms themselves can be describes as abstract and vague.

Eilon and Fowkes (1973) explore the possibility of a compromise between independent and conditional sampling. Conditional sampling referring to a method, where the simulation procedure is based on sampling from conditional probability distributions, which in themselves have already taken into account the values of other variables. Their suggestion for incorporating partial dependence is discriminate sampling. This method is based on the ability to define a range of values, which a variable might assume, given the values of other related variables. This method can be illustrated by a simplistic example, where variable x may assume values from 0–100 and variable y values from 20–80. According to subjective estimates, the value of variable y would then be in the range of 20–40 or 40–80, if variable x has a value lower or higher than 60 respectively. The method may be expanded to having several truncation points (the truncation point in the example being 60) and multiple correspondences. The illustrative example demonstrates only one-to-one correspondence. The difficulty in this method is that the determination of the truncation points is not necessarily a straight forward process. In addition since this method utilises value ranges instead of probability functions, the likelihood of a variable assuming a certain value is open to speculation.

A method of measuring partial dependencies and presenting these dependencies in quantitative form is presented by Pellonmaa (2006, 43). He suggests using Pearson's correlation coefficient as a measure for the dependence between variables. The Pearson correlation coefficient is a measure of the extent to which to variables are linearly related. The formula for this coefficient is

$$\rho = \frac{Cov_{xy}}{\sigma_x \sigma_y}, \text{ where} \tag{1}$$

X = input variable
Y = output variable
$\Delta Y/Y$ = relative change in the output variable
$\Delta X/X$ = relative change in the input variable

This method can be rather practical and straightforward assuming that there is available historic data from which the calculation can be performed. If the correlation would have to be evaluated subjectively, then this method would suffer from the restrictions of the previous methods presented in this section. This is why using this method is basically only applicable in situations where historic data is available.

3.4 Sources of Information for Risk Analysis

In the evaluation of a prospective investment, one of the most critical phases is the gathering of information. The gathered information will be the basis for the application of the chosen risk analysis model and ultimately decision making. Relevant information will be utilised to create estimates for the uncertainty involved (Hull, 1980, 36). Cooper and Chapman (1987, 93) list three types of probabilistic information, which form a comprehensive risk analysis model:

1. Probabilities particular sources of risk will occur;
2. Conditional probabilities particular scenarios will arise given the occurrence of a particular source of risk;
3. Consequence distributions, conditional on the occurrence of a particular risk.

The data required to access investment uncertainty can be found in three sources of experience: corporate, project-team or external. The main difference with these three sources is in the dispersion of the information. Corporate knowledge may be found throughout an organization, ranging from personal memories to a corporation wide database. Project-team knowledge is in the possession of individuals closely related to the project. External knowledge is often the most challenging to utilise, because it is in the possession of parties operating in the outside world. (Bowers 1994, 9) It is typical for such information to be collected via unstructured, inconsistent and less reliable channels (Pike & Ho 1991, 241). In an ideal case, relevant information from all of the mentioned experience sources should be utilised, but this may not be feasible due to for example economic or time constraints (Bowers 1994, 15).

Most of the information utilised in this study have been obtained from organizations involved in different aspects of oil pollution. The required information was gathered from external information sources for the simple reason that the internal knowledge concerning this subject was very slim within Corporation X. The advantage of utilising information from several sources was that a wider range of information was obtained and the effect of bias was decreased. The use of a wide range of information sources will also increase the internal level of knowledge in Corporation X.

Risk analysis can be constructed with two different types of information, which are subjective and historic data. Both of these forms of data can be found in the three sources of experience listed above.

Subjective Data

When a company is faced with the problem of analysing a new kind of investment opportunity, such as an investment into a new business, it is often possible that there is no previously gathered data to benefit the evaluation. In these kinds of situations, analysis of investment uncertainty has to be made based on subjective data. (Hull 1980, 36)

Several factors may affect the reliability of estimates made based on the subjective judgement of company management. Firstly, it may be difficult for management to differentiate between what they think will happen and what they would like to see happen. Also if management is later evaluated based on the estimates he or she gives now, then this situation may cause the estimates to be too conservative. (Hull 1980, 39) These are both examples of biased estimates. According to Shapiro (2005, 64) cash flow estimates based on subjective judgment will always include a side of natural bias to them, but over estimated cash flows are more easily observed, since those projects are the most likely to be approved and after the approval the actual cash flows turn out lower than originally estimated.

One technique of reducing the effect of biased estimates is the use of judgements provided by a group of people instead of only one opinion. This method may increase the reliability of estimates by decreasing the level of bias, as noted by Hull (1980) and Bowers (1994), but it may also raise new problems. These problems may involve the difficulty in combining various estimates into one single estimate and the possibility of the opinions of group members being influenced by other more dominant personalities in the group. (Hull 1980, 39)

The effect of the latter may in fact be decreased by utilising the Delphi –method of interrogation. The Delphi –method is carried out by using a sequence of questionnaires. First, the interviewee is asked to make estimates concerning the different variables. After each individual evaluation, a summary of the answers is composed and presented, again individually, to the original evaluators. The interviewees are then asked if they would like to change their original estimate in the light of the consolidated results. This process is repeated if necessary. (Hull 1980, 39–40)

Subjective judgments are usually expressed in qualitative form, but it is a requirement of the risk analysis process that subjective judgments also be transformed into quantitative form (Bowers 1994, 12). Several methods for transforming qualitative judgments into quantitative form have been suggested in literature. The most popular alternatives for this have been the fixed interval method and the variable interval method. A detailed description of these and other available methods, their validity and guides to choosing the appropriate one can be found in Hull (1980, 43-55). However, since the utilization of these methods is not required for the completion of this study these methods will not be analyzed in greater detail in the scope of this paper. I refer any parties requiring additional information to become familiarized with the above source.

Historic Data

Historic data is often referred to as objective data. The objectivity of this type of information is its main benefit, since it ensures that also all the estimates made based on historic information will also remain objective (Hull 1980, 38). The most notable hurdle in using historic data comes from the availability of relevant data from a phenomenon with a similar nature (Bowers 1994, 10). Often such information is not available, especially in a situation when an investment is directed at a new business. Risk analysis solely based on historic data would in these situations be restricted by the lack of relevant information.

The main underlying concept in the utilization of historic data is that the degree of uncertainty observed in similar phenomena in the past will be reflected on to the phenomenon under review, thus being a good indicator of its uncertainty (Bowers 1994, 11). Embedded in this is the assumption that the nature of the phenomenon will remain relatively unchanged also in the future. However, if past experience can not be considered to be an exact match for the uncertainty under evaluation, subjective estimates relevant to the particular situation should be incorporated into the historic data. These subjective estimates should complete the view of uncertainty by highlighting the discrepancies between this particular situation and the historic data.

The risk analysis done in the context of this paper is largely based on historic quantitative information. However, this numerical analysis will be supported by incorporating qualitative information. This will enable for the results to provide a more accurate description of the uncertainties involved and how the level of uncertainty might develop in the future.

4 OIL POLLUTION FROM A GLOBAL OIL COMPANY'S PERSPECTIVE

At first glance, the variables determining oil pollution costs would be simple to identify however, the situation is much more complicated in reality. In order to construct a framework for analyzing the uncertainty in these costs, they must of course first be identified and this will be done by answering the following series of questions.

1. What international agreements govern the liability of ship owners in oil spills incidents and what is the necessary insurance cover for these events?
2. Who are the insurance providers against third party claims caused by oil pollution?
3. How are direct clean-up operations of oil spills organized?
4. How are different oil pollution related claims classified?
5. What different factors contribute to the total costs of oil pollution and how do they influence each other?

These questions will be answered in the following segments. I will begin with a description of the international agreements governing the liability for third party damages caused by oil pollution. This will be followed by an explanation of the various parties related to oil pollution, oil pollution insurance and oil spill response. After that the focus will be on identifying the individual variables, which form oil pollution costs from the perspective of a global oil company and the relationships between these variables.

4.1 The Global Oil Company

For the purpose of this study a global oil company is defined as an oil company that is involved in global operations in such a way that it has a need for global oil spill response services. In addition, global involvement will mean that the oil company will be a multiple location contributor to the IOPC Funds. The details concerning the IOPC Funds will be explained later.

4.2 The International Oil Pollution Compensation Funds

In this section the interrelated subjects of the International Oil Pollution Compensation Funds (IOPC Funds), the 1969 Civil Liability Convention (1969 CLC) and the 1992 Civil Liability Convention (1992 CLC) will be explained.

4.2.1 The 1969 and 1992 Civil Liability Conventions

The 1969 and 1992 CLCs are international agreements governing the liability of ship owners for oil pollution damage. The 1969 CLC has been denounced by a large number of countries and the regime is currently set according to the stipulation of the 1992 CLC. For this reason, only the 1992 CLC will be explored in more detail. The 1992 CLC applies to two kinds of oil spills and the damages resulting from them:

1. Oil pollution damage resulting from spills of persistent oil from tankers and

2. spills of cargo and/or bunker oil from laden and in some case unladen sea-going vessels constructed or adapted to carry oil in bulk as cargo.

In order for the oil pollution damage to be covered by the 1992 CLC it has to have occurred in the territory, territorial sea or exclusive economic zone or equivalent area of a member country of the 1992 CLC. Oil pollution damage in this context is defined as loss or damage caused by contamination. This also includes measures that are taken to prevent or minimize oil pollution damage and expenses. This means that preventive measures are recoverable even when no oil spill occurs, if the threat of oil pollution damage was imminent.

If an oil spill meets the above criteria, the 1992 CLC stipulates that the owner of a tanker is strictly liable for oil pollution damage, even in the absence of fault. Except if the damage was caused by acts of war, sabotage or negligence of public authorities. The level of liability is determined by the gross tonnage of the ship involved, i.e. smaller vessels have a lower limit of liability than larger vessels. This means that a ship owner has the right to limit his liability under the 1992 CLC. However, the ship owner's right to limit his liability does not apply if it was the intent of the ship owner to cause damage or it was caused by recklessness. These limits of liability were raised as of November 2003 and are now at the level presented in the following table. Raising the limits of liability of ship owners had a significant impact on the distribution of the financial burden caused by oil pollution. The raise in these limits rolled more of the financial responsibilities to the ship owners at the benefit of other sources of compensation.

Table 1. The limits of liability of a ship owner under the 1992 CLC are presented here in Special Drawing Rights, Pounds Sterling and United States Dollars. These amounts are valid for incidents, which have occurred after 1 November 2003.

Size of ship (unit of gross tonnage)	Limit of Liability		
	SDR	£	US$
→ 5 000 tons	4.5 million	3.7 million	6.5 million
5 000 - 14 0000	4.5 million + 631 for each extra ton	3.7 million + 525 for each extra ton	6.5 million + 907 each extra ton
14 0000 →	89.8 million	75 million	129 million

Source: Secretariat of the International Oil Pollution Compensation Funds 2006

The claims for pollution meeting the standards of the 1992 CLC can only be made against the registered owner of the ship. It is then the right of the ship owner to take recourse action against other parties in accordance with national law. The 1992 CLC also creates a system of compulsory insurance by stipulating that any vessels carrying over 2,000 tonnes of oil must maintain insurance to cover its liability stipulated by the 1992 CLC.

4.2.2 The International Oil Pollution Compensation Funds

As supplementary to the 1969 CLC, the 1971 Fund Convention was set up. The 1971 Fund Convention set the regime for compensating victims of oil pollution, when the cover provided by the 1969 CLC was inadequate. These two conventions formed the old regime and the 1971 Fund Convention actually ceased to be in force as of 24 May 2002. The levels of additional coverage for oil pollution incidents applicable under the 1992 CLC are presently stipulated by the 1992 Fund Convention and the Supplementary Fund.

The 1992 Fund Convention is supplementary to the 1992 CLC and it stipulates how compensation to third parties should be made when the cover provided by the 1992 CLC is inadequate. The 1992 Fund Convention set up the 1992 Fund, which is a worldwide intergovernmental organization (list of the current 98 member countries is shown in appendix 1), to administer the regime of compensation agreed upon by the 1992 Fund Convention. Once a country ratifies the 1992 Fund Convention it automatically becomes a member of the 1992 Fund.

The exact regulations of the 1992 Fund Convention state that the 1992 Fund can be used as an additional source of compensation for someone who has suffered from oil pollution damage, but has not received full compensation under the regulations of the 1992 CLC for the following reasons:

1. The ship owner is not liable for the damage, because of one of the exemption clauses of the 1992 CLC; or

2. the ship owner is financially incapable of meeting his obligations stipulated by the 1992 CLC and his insurance is insufficient to satisfy the claims; or
3. the damage exceeds the ship owner's liability according to the 1992 CLC.

In addition to the three conditions listed above, in order for the 1992 Fund to pay compensations, the damage in question has to have occurred in a country that has ratified the 1992 Fund Convention.

The Supplementary Fund was established on 3 March 2005 as a third tier of compensation. It provides compensation in the same manner as the 1992 Fund, with the exception that the possible compensation amounts exceed the ones available from the 1992 Fund. The Supplementary Fund only deals with incidents, which have occurred after the date of its establishment. All countries that are members of the 1992 Fund may become members of the Supplementary Fund, but so far only 17 countries have ratified the agreement (appendix 2).

The International Oil Pollution Compensation Funds (IOPC Funds) is a non-profit organization, which was formed to act as a joint secretariat for the three existing funds: the 1971 Fund, the 1992 Fund and the Supplementary Fund. Although, the 1971 Fund ceased to be in force from 24 May 2002, it still exists to close incidents, which occurred before that date.

In tandem with the raising of the liability amounts of ship owners, the maximum available compensation amounts from the 1992 and the Supplementary Fund were also raised. The maximum compensation amounts, which are presently available from the 1992 Fund and the Supplementary Fund, are shown in table 2.

Table 2. The limits of compensation available for third party oil pollution damage available from the 1992 Fund and the Supplementary Fund as of 1 November 2003. The compensation amounts are presented in Special Drawing Rights, Pounds Sterling and United States Dollars.

1992 Fund	SDR	£	US$
Max. (incl. shipowners share)	203 million	169 million	292 million
Supplementary Fund (US$)			
Max. (incl. amount paid by 1992 Fund)	750 million	624 million	1 079 million

Source: www.iopcfunds.org/SDR.htm

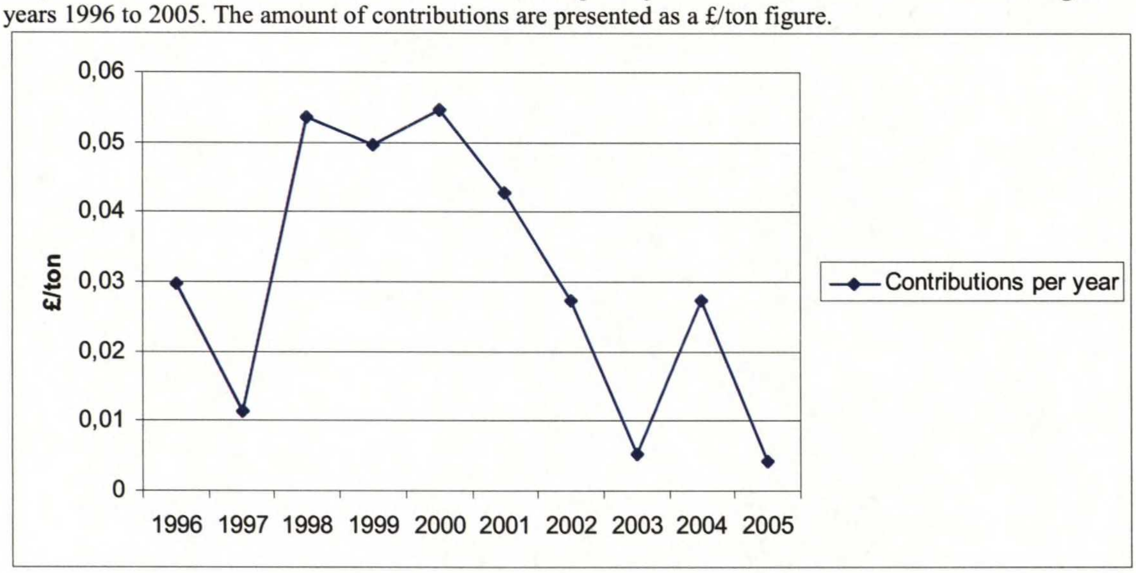
The most important issues concerning the IOPC Funds from the perspective of oil companies have to do with the financing of the funds. Since the IOPC Funds are non-profit organizations, they only require annual contributions equalling the amounts of compensations paid and the administrative costs of operating the secretariat. These annual contributions are paid by receivers of oil after sea transport. The funding of the 1992 Fund and the Supplementary Fund are both financed by the same sources, but determining the contribution amounts differs between the two funds.

Contributions to the 1992 Fund are made by entities in member countries, which receive over 150,000 tonnes of crude or heavy oil in a calendar year after sea transport. Member countries are required to submit a list of such entities to the IOPC Funds. The level of contributions levied by the IOPC Funds varies each year in relation with the amount of compensation that has to be paid. The Fund secretariat estimates at the end of each year the amount required for the next year as compensations and administrative costs. The final decision of the amount required is made by the Assembly of the 1992 Fund, which is its highest governing organ. The required amount is divided by the total amount of crude and heavy oil received in all of the member countries and as a result a per ton contribution amount is obtained. The quantity of oil received by an individual contributor is then multiplied by this per ton estimate and thus the total amount that has to be paid by that contributor is reached. The Assembly is also entitled to levy additional contributions during the year if it so sees necessary.

The basis of calculating the contributions to the Supplementary Fund follow the guidelines explained in relation to the 1992 Fund, except that all contributions to the Supplementary Fund are calculated as if at least 1 million tonnes of oil had been received by an individual entity. The figure of 1 million tonnes is used even if the actual amount of received oil is smaller.

To this day no contributions have been made to the Supplementary Fund. The development of the contributions paid to the 1992 Fund in the years 1996–2005 are displayed in graph 1. The contributions to the 1992 Funds have ranged from 0.00437 £/ton to 0.0546 £/ton. These contributions reached their peak during the turn of century, but it can clearly be derived from the illustration below that the contribution amounts have been declining in recent years. It is the opinion of the Deputy Director of the IOPC Funds that the present trend will continue in the future and upcoming contribution amounts will possibly be even lower than they are at present. This trend is due to the decline in the number accidents, which would require for the IOPC Funds to pay compensations and also to the fact that more of the liability for oil pollution compensation has been moved to the ship owners after the raise in ship owner liability amounts under the 1992 CLC. He even speculated with the idea that there would not be a need for the IOPC Funds at all in the future.

Graph 1. The development of the contribution amounts paid by receivers of oil to the 1992 Fund during the years 1996 to 2005. The amount of contributions are presented as a £/ton figure.



Source: Secretariat of the International Oil Pollution Compensation Funds 2006

4.3 The P&I Club

As mentioned before, the 1992 CLC stipulates that any ship carrying over 2,000 tonnes of oil must be insured to cover the ship owner's liability of third party oil pollution claims. This system of compulsory insurance creates the need for oil companies to uphold P&I (Protection & Indemnity) insurance. The providers of such insurance are non-profit organizations called P&I clubs. Because it is compulsory to have such insurance, the payments to P&I clubs can be considered mandatory costs for oil companies.

The annual payments to the P&I clubs are referred to as calls and not premiums as in traditional insurance. The amount of annual calls is dependant on four factors: 1) the incident record of the individual client, 2) the incident record of the P&I club as a whole, 3) the re-insurance costs of the club and 4) the administrative costs of the club. Because the level of calls depends on these factors, they can be considered variable costs on a yearly basis. Only the administrative costs of the club can be considered fixed from year to year. Since all P&I clubs are non-profit organizations, they will only issue calls to cover the amount required to pay compensations and administrative costs.

Based on the above information, it can be said that the calls paid by global oil companies are totally dependent on the amount of third party oil pollution claims. P&I clubs don't for example compensate clients for having an effective oil spill response system with lower calls. The only way to lower calls is to lower the amount of third party oil pollution damage.

There are two unique features in P&I insurance. The first one is that because annual calls are dependent on the overall incident record of a club, a member can have high annual calls even if they themselves have a clean incident record. The second unique feature is that the P&I clubs can, if they see necessary, make supplementary calls during the year. For these two reasons, global oil companies are not just members of a single P&I club. As a risk reduction measure, they split their P&I insurance cover between several P&I clubs. As an example, BP is a member of three P&I clubs. The incident history of these clubs is also reviewed by the oil companies on a regular basis.

4.4 International Group of P&I Clubs

The International Group of P&I Clubs (IGP&I) is comprised of 13 P&I clubs. Together these 13 clubs provide liability cover for approximately 90 % of the world's ocean-going tonnage. This figure includes all sea transported cargo, not only the transport of oil. The IGP&I was formed to enable an effective system of pooling exposure and risk above certain limits of retention. This would then enable the required level of cover for ship owners to be provided by the individual P&I clubs. In other words it is a form of risk reduction against third party claims faced by the P&I clubs and their clients. The IGP&I is meaningful for global oil companies, because the P&I clubs used by them have to be members of the IGP&I.

The principle task of the IGP&I is to co-ordinate the operation and regulation of the Pooling Agreement. Amongst other things, the Pooling Agreement governs the financial relationship between the member clubs. In the scope of this research the most important parts of this agreement are the chart of reinsurance and the contribution formula.

The chart of reinsurance is divided into two halves (appendix 3). The first one is protection and indemnity and the second one is oil pollution. These halves have been separated, because the liability of oil pollution is capped at US$ 1.05 billion, but the limit of liability for protection and indemnity goes up to about US$ 5.5 billion. The most important aspect of the chart of reinsurance is that it stipulates that all claims under US$ 6 million are retained at the individual clubs. However, all qualifying claims over that figure are pooled between the group clubs. In other words, the member clubs reinsure each other for claims exceeding US$ 6 million. The contribution amounts of the individual clubs to these pooled claims are based on the contribution formula.

With the contribution formula (appendix 4) the IGP&I is able to calculate how much any given member club is obliged to pay of a pooled claim. Essentially that amount is dependant on three variables: 1) the amount of tonnage the club has as a percentage of the total tonnage of the group, 2) the premium income of the club as a percentage of the premium income of the whole group and 3) the claims record of the club as a percentage of the claims record of the group. This means that the contribution amount is dependent on the size of the member club along with its historical incident record.

4.5 Oil Spill Response Limited

Oil Spill Response Limited (OSRL) is a non-profit making limited liability company offering global oil spill response services. In addition, OSRL offers training and consultancy services for the purpose of improving the oil spill handling procedures of its clients.

The historical background of OSRL goes back to the oil spill from the tanker Amoco Cadiz in 1967. The Amoco Cadiz was carrying an oil cargo owned by BP. Due to the lack of other available methods; dispersants was the primary method of clean-up used. The dispersants caused severe damage to the environment and consequently to the image of BP. As a result, BP began acquiring a stock pile of equipment and training personnel to prepare for possible similar future situations. At that point, the predecessor of OSRL was formed.

The accident of the tanker Torrey Canyon and the financial burden of keeping up this sort of oil spill response preparedness were the knock on effects, which resulted in BP asking for other major oil companies to help maintain this new system. At that time, the present day model of OSRL was formed by its original members BP, Exxon, Petro Canada, Texaco and Mobil. OSRL experienced again large growth after the Exxon Valdez accident, which forced other oil companies to analyze their preparedness to be able to handle oil spills of that nature. Currently OSRL is owned by 31 international oil companies, including all the biggest oil companies in the world.

OSRL offers memberships in three different levels, with varying services and charges. The three membership levels are shareholder, associate and shipping associate memberships. Associate and shipping associate memberships can be considered lower level memberships and are suitable for companies requiring the services of OSRL, but on a localised scale. In order to become a shareholder member, the applicant is required to be an international oil company.

Once an oil company has been accepted as a shareholder member, it also becomes one of the owners of OSRL. Naturally the annual fees paid by the shareholder members are higher compared to the annual payments of lower level members. Higher payments also entitle the shareholder members to more control in the organization and all of them have a member on the Board of OSRL.

In this study I will focus on the services provided to the shareholder members and the charges they pay in exchange for those services. This study will also exclude the training and consultancy services from further examination. From this point on, only the oil spill response services are meant when referring to the services provided by OSRL.

4.5.1 The Operation of OSRL

When joining OSRL, a global oil company signs a contract which covers all the services provided by the organization. The advantage of this is that no further legal matters need to be solved in a possible emergency situation, thus improving oil spill response time. A membership guarantees 24 hour 365 days per year on call response and advice services.

Oil spills are categorised according to a so called TIER-system by their severity and resource requirements.

TIER 1) These oil spills are considered small and are usually handled locally by the responsible party with its own resources.

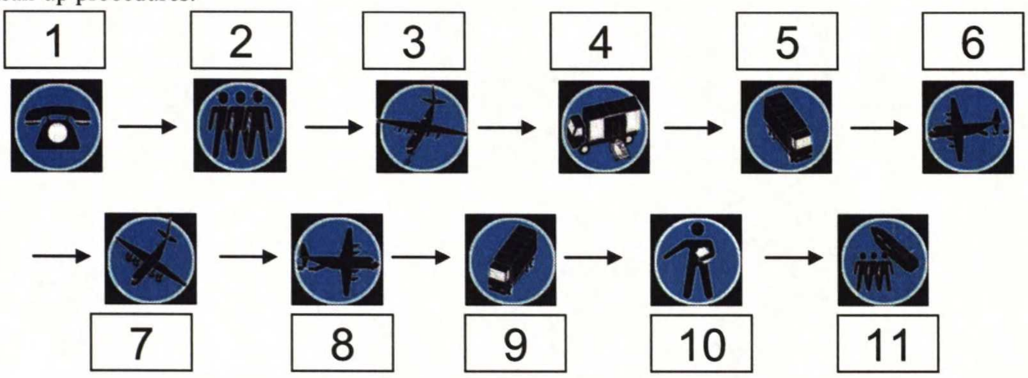
TIER 2) TIER 2 incidents are medium size spills and remain at such a level that the required oil response resources are able to be moved to the site within a few hours. These types of incidents are usually handled by local government with possible aid from a regional co-operative.

TIER 3) TIER 3 oil spills are the most serious and are categorised large. Oil spills of this magnitude are handled by central and local government. National or even international co-operation is often needed in the form of shipment of available people and equipment.

OSRL offers TIER 2 and 3 level services and they are the provider of TIER 3 level global oil response services for global oil companies.

When a client contacts OSRL to report a TIER 3 level oil spill, OSRL launches its response operations, which they present in the following way:

Figure 4. The operating procedure of OSRL demonstrated from the initial client contact up to the initiation of clean-up procedures.



1. **Call Out.** Client makes contact with OSRL and key questions are answered with regard to the equipment and personnel needed.
2. **Mobilise staff.** The required staff is mobilised from an "on duty" staff.
3. **Get Aircraft.** Air transport is acquired for personnel and equipment, either by using OSRL's own Hercules plane or from an outside source.
4. **Load trucks.** Trucks are loaded with pre-packaged equipment.
5. **Transport to airport.** Response equipment is transported from secure facilities to place of departure.
6. **Load aircraft.**
7. **Flight.** A response technician travels with the equipment. Other OSRL staff can travel on the same flight or on a separate flight depending on the situation.
8. **Unload.** Client meets the equipment and OSRL staff at the airport.
9. **Transport to site.** The client arranges transportation to the site.
10. **Management.** OSRL integrates into the client's management structure and receives support from other OSRL employees.
11. **Operations.** OSRL's staff begins work alongside with the crew of the client.

Source: www.osrl.org/services/index.html

OSRL has clearly defined the responsibilities between OSRL and the client in an oil spill situation. OSRL is responsible for activities up to and including the flight, which transports the required equipment to the appropriate airport. In addition to arranging air transportation and aiding with customs and immigration, these activities include compiling a suitable package of OSRL personnel and equipment and informing the client of the price and transportation requirements for that package. The responsibilities of the client include meeting the equipment and personnel after air transport and providing onward transportation to the actual spill site. The client is also responsible for ensuring sufficient insurance cover is provided for equipment, compiling a response management team and providing accommodation for possible OSRL personnel accompanying the equipment.

The aim of OSRL is to be able handle two simultaneous 30,000 ton crude oil spills or two simultaneous 10,000 heavy oil spills. Because OSRL is the global oil response service provider to several oil companies, it can not make all its resources available to only one of its customers at any given time. Theoretically, the first client to contact OSRL for oil spill response is entitled to 50 % of all resources. If a second spill should occur after that, then that client could receive 50 % of the remaining resources and so on. According to the representative of OSRL, this operating policy is theoretical. In reality the requirements of every oil spill is evaluated individually and in an event of a major spill it is possible to deviate from this pattern.

Since the year 2000, OSRL and East Asia Response Limited (EARL) have formed a global alliance. EARL is a company operating in very similar fashion to OSRL and it is based in Singapore. This close relationship has the benefit that the members of OSRL can also get use of the resources of EARL with out extra charge and vice versa. The additional benefit is that OSRL can co-ordinate its operations more effectively, because it has the possibility of shipping out equipment and personnel from either or both locations. Naturally the amount of available resources is also higher.

4.5.2 The Pricing Policy of OSRL

It is possible to divide the costs of OSRL oil spill response services in a clear cut way into fixed and variable costs.

When an oil company signs a contract with OSRL, it pays a joining fee of £ 50,000. This joining fee is used by OSRL as investment in the equipment stockpile. In addition to paying the joining fee, which is naturally paid only once, the shareholder members are still responsible for paying an annual fee. The amount of the annual fee varies depending on the volume of world-wide production of the oil company plus a measure of imported oil. These fees comprise the fixed part of OSRL costs and are summarized in table 3.

Table 3. A summary of all of the fixed costs generated from a shareholder membership in OSRL. The size of the oil company is presented as barrels / year and the annual payments in Pounds Sterling.

Participant level	Size (bbls pa)	Payment pa (£)
Band 1	>400	382 200
Band 2	300-400	254 800
Band 3	200-300	127 400
Band 4	0-200	63 700
Joining fee		50 000

Source: OSRL Yearbook 2006

All the oil companies that are considered global, in the scope of this study, can be assumed as being band 1 participants and there for they would be charged an annual fee of £ 382,200. According to OSRL, the level of these annual payments has remained relatively stable and they are more likely to decrease than increase due to more members joining and contributing to the division of costs.

In addition to the fixed yearly payments, a shareholder member also pays for equipment and personnel rental for every oil spill they contact OSRL to handle. These rental fees constitute the variable costs for the services of OSRL.

When OSRL responds to a clean up operation, it charges either on a per day, per run or per costs incurred basis. Depending on what equipment or personnel is used by the client. The applied per day fee varies depending on if the equipment is in use or if it is on stand by. OSRL defines the total rental period as beginning from the moment the equipment leaves the OSRL response base in Southampton or the EARL response base in Singapore, until the equipment is returned to the same base or to another agreed location. The daily stand by fee is charged for any day or part of a day, for any period of time, that the equipment leaves the response base for the spill site and until it is returned to the response base, except for the time when the equipment is in use. The time when the equipment is in use is defined as any day or part of a day, for any period of time, when the equipment is deployed into response operations in the field or is removed from the forward storage area. OSRL has defined a stand by or a higher "in use" fee for every individual piece of equipment and member of personnel it has available.

Because of the non-profit status of OSRL, they have not added a significant profit margin onto their equipment and personnel hire rates. The rental fees have been calculated on a depreciation basis. For example, if a certain type of boom is used in operations for 30 days, it has to be replaced. That is why the daily "in use" fee is calculated by dividing the asset value of that boom with 30 days. The standby fee is then half the value of the "in use" fee.

Even though financial gain is not an objective of OSRL, on certain fiscal years the payments they receive exceed their costs. In these situations, it would be normal to assume that this excess money would be distributed back to the shareholder members. However, in OSRL this is not the case. According to the representative of OSRL, it used to be their policy to repay any possible profit back to the shareholder members. However, this policy was changed at the initiative of the oil companies. The reason for this was simply administrative. The oil companies preferred to contribute to the operations of OSRL according to a set budget, instead of having to repeatedly review these cost figures at the end of the year. As a result, OSRL changed their policy in agreement with the shareholder members. Currently any remaining profit is invested by OSRL as they see most appropriate, which typically refers to an upgrade in their equipment.

5 ANALYSIS OF THE UNCERTAINTY IN OIL POLLUTION COSTS

5.1 The Different Cost Factors of Oil Pollution

This study will only analyze the cost factors of oil spills, which occur at sea and are not caused by

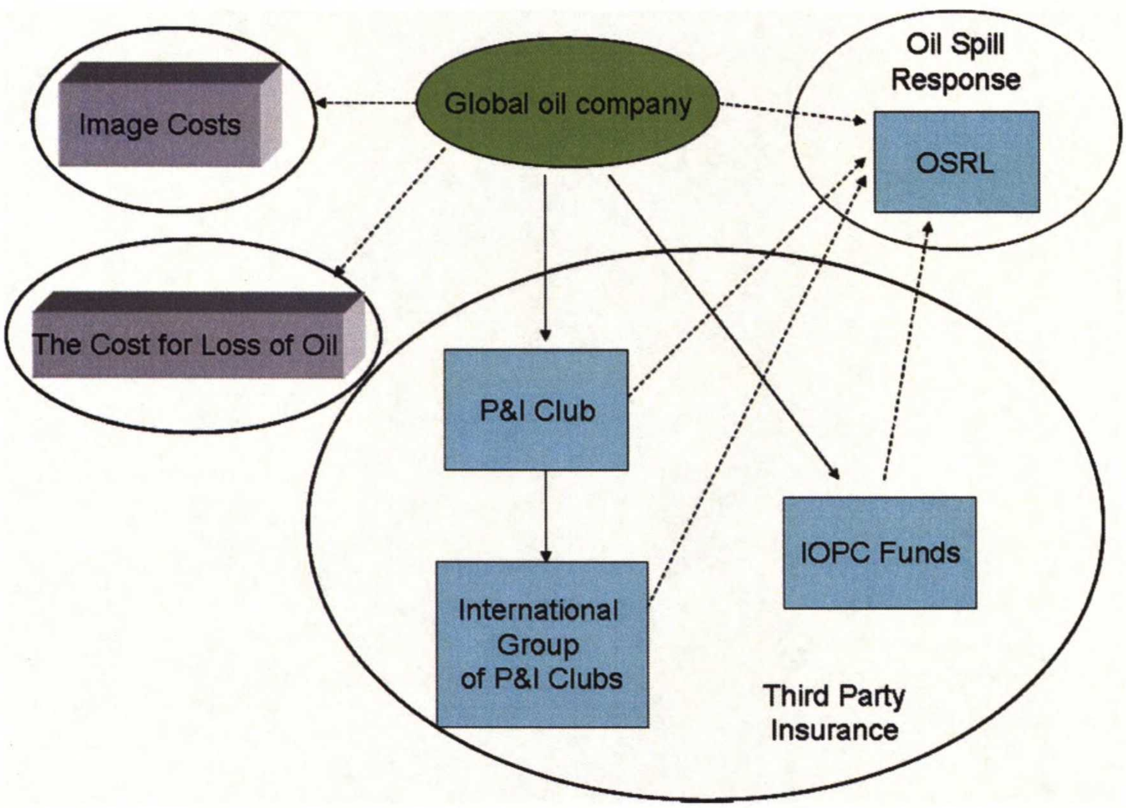
1. act of war or grave natural disaster; or
2. sabotage by a third party; or
3. the negligence of public authorities in maintaining lights or other navigational aids: or
4. the ship owner's intent to cause such damage; or
5. by the recklessness of the ship owner.

The above situations can be considered exceptional and in addition, these situations are not covered by the 1992 CLC. This means that the same rules of compensation as for oil spills occurring in a "normal" situation do not apply.

This study will also not analyze the costs of oil spill incidents, which have occurred in countries, which have not ratified the international compensation agreement, i.e. 1992 CLC. In these countries the compensation system is not unified and it is mostly based on country specific legislation. There for it is not possible to include incidents occurring in these countries into the scope of this study. It is worth noting that the United States is amongst the countries, which fall into this category and the regime and compensation system adopted in the United States can be considered unique. Because of it unique features, it would be a suitable topic for another research and it is only possible to scratch the surface of this system here. It can only be said, that in general under the legislation of the United States the liability of a ship owner is much higher than in countries, which have ratified the 1992 CLC (Nichols & Morgan, 2004, 3). This means that the financial risk for oil companies operating in the United States is higher than in other countries.

Previous research of oil spill costs, such as Moller et. al. (1987, 123), have divided costs into two categories: clean-up and damage. This study will widen that point of view and introduce new cost factors. These new cost factors are evident when the subject is analysed from the point of view of a global oil company and cost factors which are not attributable to any specific oil spill incident are introduced. This is the reason why it is more appropriate to refer to these cost factors as oil pollution costs rather than oil spill costs. In this study the division of oil pollution costs will be made between four sources. These sources are oil spill clean-up costs, third party insurance costs, image costs and the costs from the loss of oil. The relationship between these four cost factors is illustrated in figure 5.

Figure 5. This diagram details the different variables, which form total oil pollution costs and the relationships between these variables. The variables are illustrated by the circled entities. The simple rectangles connected with arrows represent different organizations involved. The dashed arrows represent the cost directly generated by a single oil pollution incident. The regular arrows are the cash flows generated by the existence of oil pollution in general.



As previously stated the cost factors illustrated above are not all attributable to any specific oil spill incident. Oil spill response, image and loss of oil costs are generated by a specific oil spill, where as the costs of upholding third party insurance is attributable the existence of oil spills in general. The term costs of oil pollution will be used as a common denominator for all of the four factors.

Direct clean up cost are generated by situations when the oil company has to use the services of an oil clean up service provider. In this case, the service provider focused on is OSRL. The costs of using these services are sometimes paid by the insurers and sometimes directly by the oil company. The oil company would responsible for compensation for example in situations when they want to continue oil spill clean-up operations beyond the point assessed economically reasonable by the insurer. Thus the insurer would compensate for the part they assess as being reasonable and the oil company would be responsible for the rest.

Third party insurance costs are comprised of calls paid to the P&I club, which also guaranties the financial support offered by the IGP&I, and the annual contributions paid to the IOPC Funds. In other words the cost generated upholding insurance cover against third party claims.

This study will analyze the image costs of oil spills by studying the possible effects of oil spills on oil company share prices. The final cost factor, the costs from the loss of oil, can naturally be measured by the economic value of the oil lost in a spill.

The four cost factors and their relationships shown in figure 5 will be used as the framework for evaluating the uncertainty in oil pollution costs. In an ideal situation, this analysis would follow the guidelines of sensitivity and simulation analysis explained in previous sections of this paper. This would provide a clear indication of the effect on total oil pollution costs of the individual and combined uncertainty of the variables listed above. However, because of the lack of available historic data of all the variables, a straight forward sensitivity and simulation analysis is not feasible. More specifically no information of level of calls paid to the P&I clubs or the amount of contributions paid to the IOPC Funds could be obtained. The other alternative would be to incorporate subjective judgement to replace the missing historical data, but this type of information is also unavailable. As a result, the evaluation of uncertainty in oil pollution costs is forced to be presented in a modified form.

The analysis in this paper will be similar to the analytical methods of risk analysis presented by Aho (1980), which were explained earlier. The uncertainty of the phenomenon as a whole will be evaluated on the basis of the statistical characteristics of the related components. This analysis of the statistical parameters of each individual variable will provide an indication of their uncertainty. After this analysis has been completed, the combined uncertainty of all of these factors will be evaluated by incorporating qualitative information obtained from the interviews done for this research.

All the calculations have been performed on the Microsoft Excel spreadsheet program. As the historical data on which the calculations will be based on, this study will use the information provided by the IOPC Funds from the oil spill incidents that organization has been involved in. The details of this data will be explained in the next section, after which the risk analysis of the individual cost factors will follow.

5.2 The IOPC 1971 Fund and 1992 Fund Incidents

The IOPC Fund has listed in its 2005 annual report all the incidents in which the IOPC Funds have been involved in the role of compensator. This list extends from 1970 to the end of 2005. Up until that point claims in 107 oil spills had been made against the 1971 Fund and the respective number was 29 for the 1992 Fund. Thus the combined number of incidents handled by the two funds on 31 December 2005 was 136. The last incident handled by the 1971 Fund occurred on 28 May 2001. Of those incidents the funds have either paid compensation or the claims are pending in 127 cases. In the remaining 9 incidents, the claims against the funds were either withdrawn or no claims were pursued. Since the 1971 Fund has already ceased to be in effect, the number of claims against this fund will not rise. However, the number of claims handled by the 1992 Fund will rise as new oil spill incidents take place.

The total sample for this study consists of the data from 122 incidents. The reasons for this are the following. There exists overlapping information between the 1971 Fund information and the 1992 Fund information in 5 incidents. In overlapping situations the information from the 1992 Fund was used. In addition to this, the data from the oil spill incident involving the vessel Haven in 1991 was disregarded from this study, because the IOPC Funds had categorized its costs in a manner deviating from the manner of how the costs in all of the other incidents were categorized. This resulted in the data not being comparable with the rest of the incident data. All IOPC Fund incident information used in this study is shown in appendix 5.

The amounts of compensation paid in the IOPC Fund incidents are according to their 2005 annual report the total amounts of compensation paid relating to that oil spill. This means that there are three possible alternatives for what organization actually paid the compensation. The compensation amount might have been completely paid by the ship owner's insurer, one or both of the IOPC Funds or then the compensation amount might have been divided between the ship owner's insurer and the IOPC Funds.

A number of the incidents are at the present time still open, meaning that relevant claims have been made, but so far total compensation has not yet been paid. The compensation amounts in these cases might still change from the information presently available, but for the purpose of this study it is assumed that all claims will be settled for the presently available amounts.

The IOPC Funds have divided the grounds for claims in total into eight categories:

1. clean-up
2. preventive measures
3. fishery-related
4. tourism-related
5. farming-related
6. other loss of income
7. other damage to property

8. environmental damage/studies

For this study, this categorization has been consolidated into two groups. This division is in line with the framework of different oil pollution costs used. The first group is referred to as oil spill clean-up costs, which is comprised of clean-up and preventive measure claims. The second group of costs is third party damage or compensation, which is comprised of fishery-related, tourism-related, farming-related, other loss of income, other damage to property and environmental damage/studies claims.

Because The IOPC Fund incident data is originally presented in various currencies and ranges from 1979 to 2005 two alterations were required. All amounts were first converted into Pounds Sterling and after that adjusted for inflation to improve comparability. The conversion rates were obtained from the Thomson Financial Datastream database and the inflation adjustment was made with the use of the Producer Price Index (PPI) provided by the website of the Office of National Statistics in the United Kingdom. The PPI is a monthly survey that measures the price changes of goods bought and sold by manufacturers in the United Kingdom.

5.3 Direct Clean-up Costs

The revision of the basic operating and pricing policies of OSRL has been an important aspect of this research. Even though they have a significantly open policy in providing information about these matters, they still considered historic incident data too sensitive to be released. In the absence of this information, the clean-up costs taken from the IOPC Fund incident data will be used as a proxy and the evaluation of oil spill clean-up costs will be made on the basis of that information.

Since the IOPC Funds have not specified the entities responsible for clean-up measures in the incident information, it is not possible to detail how the clean-up operations were organized in the spills under analysis. However, one of three approaches is possible in the organization of clean-up efforts. Governments may choose to independently carry out clean-up operations with their own resources, they may require for the responsible party to handle the situation with the aid of outside service providers, such as OSRL, or the third alternative being that several entities combine their resources. As the amount of spilled oil increases, so does the probability of several parties being involved. This is caused by the fact that presently the resources available to a single operator are insufficient to independently handle the clean-up of a greater size oil spill.

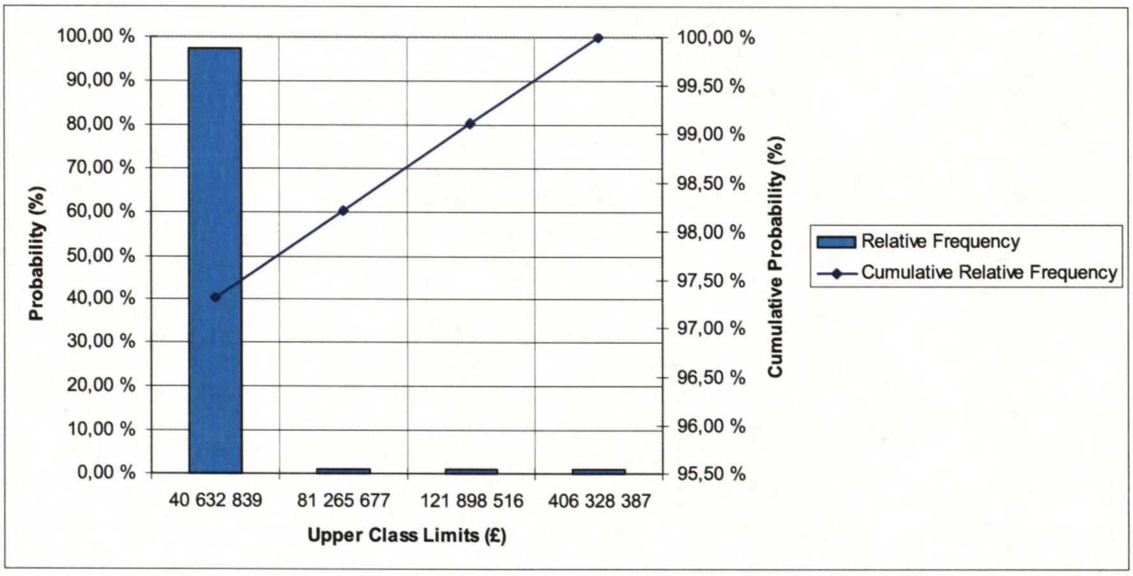
The uncertainty of oil spill clean-up costs will be evaluated by descriptive statistical analysis and focusing on the dispersion of values as an indicator of uncertainty. Another point of interest is to explore a possible relationship between the amount of oil spilled and the resulting clean-up costs. A possible relationship between these variables would be very beneficial in a rough assessment of possible clean-up costs if only the amount of oil spilled is known.

Compensation for clean-up has been paid for in 122 of the incidents reported by the IOPC Funds. This represents 92 % of the total sample. The number of incidents from which both the amount of oil spilled and the amount of clean-up compensation were available amounted to 88, representing 72 % of all incidents and 79 % with information available for clean-up costs.

5.3.1 Statistical Analysis

The distribution of oil spill clean-up costs can best be described as being positively skewed and having a wide range of values. These two facts become apparent when the values are illustrated on a relative frequency distribution.

Graph 2. This graph illustrates the relative frequency and cumulative relative frequency distributions of historic oil spill clean-up costs. These costs have been divided into four separate classes and the upper boundaries of each respective class are shown on the x-axis. The first three classes are of equal size (£ 40,632,839) and the fourth is composed of incidents with values ranging from £ 121,898,516 to £ 406,328,387. This division has been done to improve the readability of the graph.



The majority, 97.32 % to be precise, of all clean-up costs are situated between £ 0 and £ 40,632,839. In fact only three incidents have generated higher clean-up costs than this value. These three incidents were the oil spills of Tanio in 1980, Nakhodka 1997 and Prestige in 2002, which resulted in clean-up costs of £ 47,521,232, £ 109,357,499 and £ 406,328,387 respectively.

The distribution of clean-up costs has a skewness coefficient of 9.32. This indicates that the distribution is extremely skewed to the right, because the skewness coefficient for a normally distributed variable would be 0.

A more precise description of the dispersion of clean-up costs can be obtained by calculating the value of the median in addition to the lower and upper quartiles. The median is a better measure for "average" in this situation than the mean, because of the skewed nature of the distribution. The median for clean-up costs has a value of £435,560, which means that 50 % of these costs have been less than this amount and 50 % have been higher. The lower and upper quartiles have values of £ 62,324 and £ 2,175,481 respectively. These results consolidate even more the evaluation that oil spill clean-up costs can for the most part be considered small.

As mentioned the other significant matter about this distribution is its wide range of values. The smallest amount paid as compensation for oil spill clean-up has been £ 504, but the largest amount has been £ 406,328,387. This results in the distribution having a range of values of £ 406,327,883, which can be considered significant. In other words, if the if the dispersion values is used as a measure of the uncertainty of a variable, then the clean-up costs generated by oil spills can be defined highly uncertain.

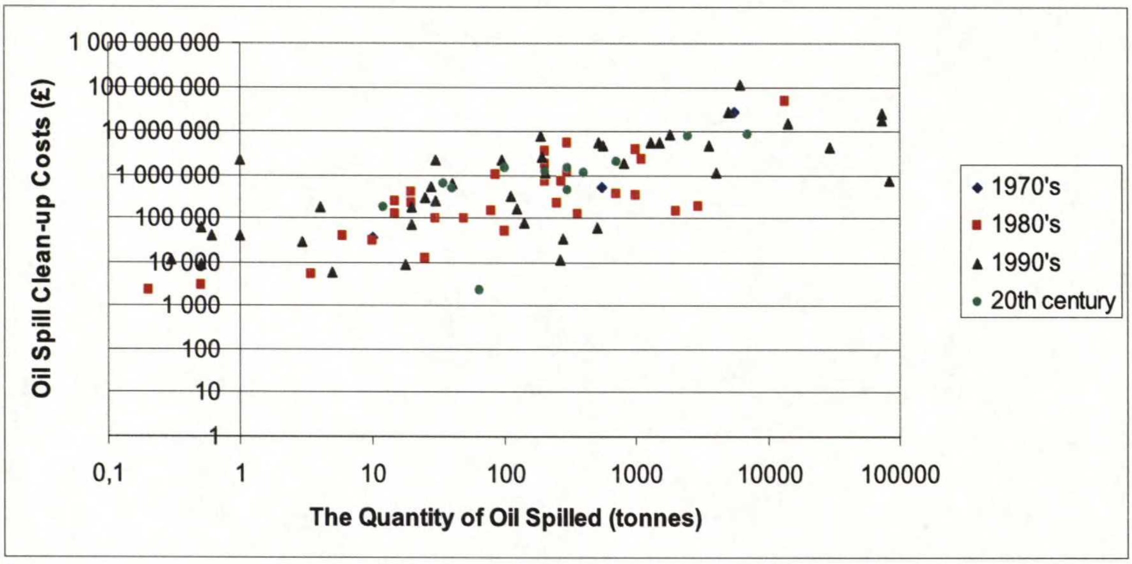
Table 4. A summary of the descriptive statistical key figures of oil spill clean-up costs.

Key Figures: Clean-up Costs	
Mean	7 431 803
Median	435 560
Standard deviation	39 911 804
Skewness	9.319
Area	406 327 883
Minimum	504
Maximum	406 328 387
Q1	62 324.322
Q4	2 175 481.163
Number of Values	112

5.3.2 The Relationship between Amount of Oil Spilled and Clean-up Costs

In addition to analyzing the statistical parameters of oil spill clean-up costs, the second point of interest for this study is to explore the possibility of a relationship between the amount of oil spilled and the resulting clean-up costs. A rough visual illustration of this relationship can be obtained from a scatter plot of these two variables.

Graph 3. A scatter plot illustrating the relationship between the amount of oil spilled and resulting costs of oil spill clean-up. The incidents are categorised by decade, ranging from the 1970's to the 20th century. Both variables are shown on a logarithmic scale to aid visual analysis.



A visual interpretation of the scatter plot would indicate a slight positive correlation between clean-up costs and the amount of oil spilled, i.e. higher volumes of spilled oil would result in higher clean-up costs. This is a natural hypothesis, because the more spilled, usually the more rigorous are the clean-up efforts required and this will naturally increase costs.

To obtain a more precise qualitative estimate of the relationship between these variables, two types of analysis will be carried out. The two tests are a correlation analysis and a regression analysis, more specifically ordinary least-squares regression (OLS) analysis. The general issues regarding these types of analysis will be assumed to be known and will not be discussed at great length here. However, a short description of basics will be provided.

The correlation analysis will provide an indication of the direction and strength of the relationship between the quantities of oil spilled and oil spill clean-up cost. The correlation coefficient has a value ranging from -1 to 1. The closer the value is to -1 or 1, the stronger the relationship. A positive value will indicate a positive relationship, i.e. higher quantity of spilled oil results in higher clean-up costs. The opposite is true for negative values.

OLS explores the possibility of describing a possible linear relationship in mathematical form. The relationship will be expressed in the following way:

$$Y = \alpha + \beta X + e, \text{ where} \tag{2}$$

Y	= dependent variable
X	= independent variable
α	= the point where the regression line intercepts the y-axis
β	= the gradient of the regression line
e	= residual

The aim of OLS is to draw a line in the scatter plot of the variables, where the sum of the residual squares is minimised. In order to carry out the regression analysis, it is assumed that the clean-up costs are the dependent variable (Y) and the amount of oil spilled is the independent variable (X). A significance level of 5 % is appropriate for analysis at this level. The null hypothesis (H_0) is that there is not a linear relationship between the two variables. The counter hypothesis (H_1) is that there is a linear relationship. The results of the correlation and regression analysis are summarized in table 5.

Table 5. Summary of the results from the correlation and regression analysis of oil spill clean-up costs and the amount of oil spilled.

Regression key figures	
Multiple R	0.228
R-squared	0.052
Adjusted R-squared	0.041
Standard Error	13 195 039.642
Observations	88

	Coefficients	*Standard error*	*t-statistic*	*P value*	*Lower 95%*	*Upper 95%*
Intercept	3 551 222.414	1 458 514.913	2.435	0.017	651 790.786	6 450 654.042
Variable X 1	215.047	98.951	2.173	0.033	18.340	411.754

The regression analysis provides the following mathematical form for the linear relationship between these variables:

$$\text{Clean-up costs} = 3{,}551{,}222.414 + 215.047 * \text{Amount of oil spilled} \tag{3}$$

This would mean that if zero tonnes of oil were spilt, the clean-up costs would be about £ 3.5 million, which in reality is not a reasonable assumption, and that clean-up costs would increase by £ 215 by every additional ton of oil spilled. Because the p value of variable X

(0.0325) is lower than our selected level of significance (5 %), H_0 can be rejected and stated that there exists a linear relationship between clean-up costs and the amount of oil spilled. In addition, because the p value is between $0.01 < p \leq 0.05$ the linear relationship can be described as statistically almost significant. However, it is not sufficient to only assess the statistical significance of the relationship; the content significance must also be evaluated.

An indication of the content significance can be obtained from the values of the correlation multiple (multiple R) and the square of the correlation multiple (R-squared), the coefficient of determination. These values will show how well the above equation explains the linear relationship between the amounts of oil spilled and clean-up costs. The correlation multiple R has a value of 0.228. This value confirms the initial visual assessment of the scatter plot, in which a positive relationship was hypothesized. However, because the value of the correlation coefficient is so close to zero, this relationship can only be described as weak. The value of R-squared is only 0.0521, which means that only 5.21 % of the change in clean-up costs can be attributed to the change in the volume of spilled oil. In other words, the equation, which was obtained from the results of the regression analysis, is not a good indicator of the relationship between oil spill clean-up costs and the amount of oil spilled.

This result is in line with previous research, such as White and Molloy (2003) and Etkin (1999), which have studied the relationship between these two factors. The variety of relevant factors affecting the oil spill clean-up costs diminish the impact of the amount of oil spilled. Previous research indicates that more important factors seem to be the type of oil spilled, in addition to the location and pattern of the spill. The influence of these factors in determining the oil spill clean-up costs can not be carried out in this study due to lack of relevant information.

Because the results of OLS only indicated a weak relationship between the variables, it is still possible to explore the possibility of a non-linear relationship. There are two options in how this analysis can be carried out (Watsham & Parramore 1997, 210):

1. Transform the data and apply linear analysis.

2. Apply non-linear regression techniques.

The guidelines presented by Watsham and Parramore (1997, 210–211) for the first alternative will be followed. To explore the possibility of the variables having a relationship in the following form $Y = \alpha * X^{\beta}$, a natural logarithm of the values of clean-up costs (Y) and quantities of oil (X) must first be taken. The OLS methods can then be applied to these values. This provides the following results:

Table 6. Summary of the results of the non-linear regression analysis between oil spill clean-up costs and amount of oil spilled.

Regression Key Figures	
Multiple R	0.736
R-squared	0.541
Adjusted R-squared	0.536
Standard Error	1.660
Observations	87

	Coefficients	*Standard Error*	*t-statistic*	*P value*	*Lower 95 %*	*Upper 95 %*
Intercept	10.025	0.348	28.796	1.296E-45	9.333	10.717
Variable X 1	0.614	0.0613	10.012	4.871E-16	0.492	0.736

The results have to still be transformed back into a non-linear form and as a result the following is obtained:

$$\text{Clean-up costs} = 2{,}449.487 * \text{Amount of spilled oil}^{0.614} \quad (4)$$

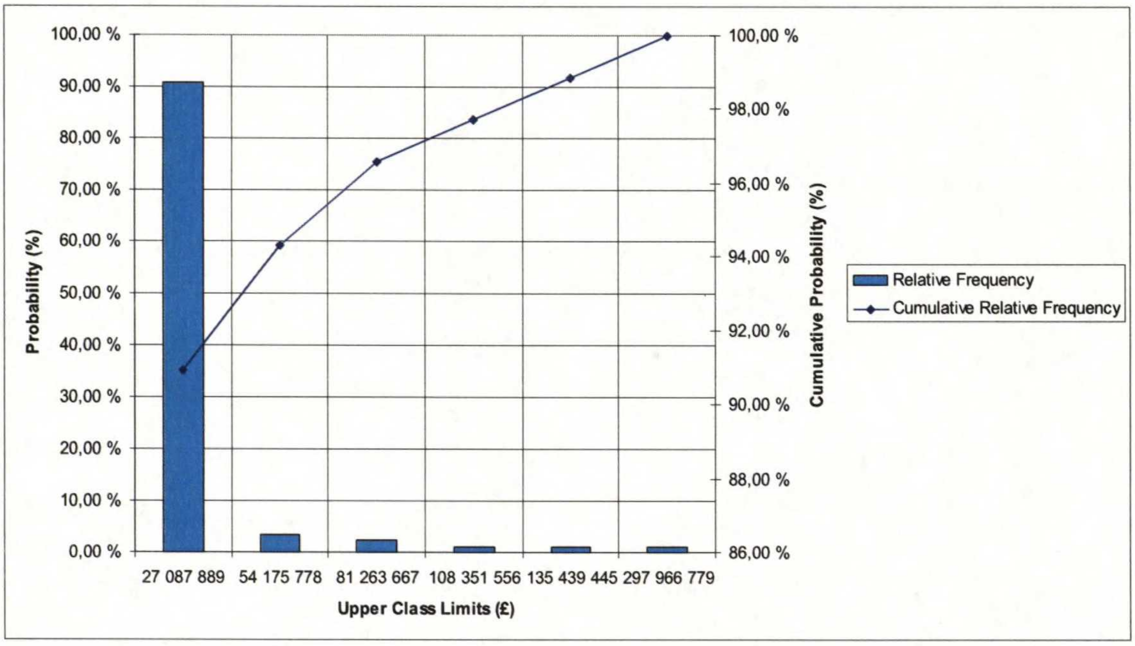
This non-linear equation is describes the relationship between the variables in a more precise way, because the multiple R has a value of 0.736, which indicates a significant positive correlation and as R-squared has a value of 0.541, the amount of spilled explains 54.1 % of the increase in clean-up costs.

5.4 Insurance for Third Party Claims / Oil Pollution Compensation

The costs generated by upholding insurance against third party oil pollution claims consist of the calls paid to the P&I clubs used by the oil company and the annual contributions paid to the IOPC Funds. It is not possible to evaluate the exact level of either of these payments, because such information was considered confidential by the oil companies, the P&I Clubs and the IOPC Funds and there for could not be used in this study. There for the analysis related to third party oil pollution compensation must also be carried out with the aid of a proxy. Since it was earlier established that both the calls paid to the P&I Clubs and the contribution to the IOPC Funds are in direct relation to the amounts of compensation paid to third parties for oil pollution damage, it is possible to utilise the relevant information provided by the IOPC Fund incident data for this analysis.

The distribution of other types of compensation can be described in similar fashion as the distribution of oil spill clean-up costs. This distribution is also characterized by strong positive skewness and a wide range of values.

Graph 4. This graph illustrates the relative frequency and cumulative relative frequency distributions of third party oil pollution compensation. The distribution is divided into 6 classes and the upper limits of these classes are shown on the x-axis. The first five classes are of equal size, £ 27,087,889, and the last one is composed of values ranging from £ 135,439,445 to £ 297,966,779.



Over 90 % of incidents have resulted in less than £ 20,571,594 of compensation being paid for third party damage and fall into the first class. The other three classes constitute in total of only eight incidents. A skewness coefficient value of 6.05 is another indication of the values concentrating on the lower end of the distribution. A more detailed representation of the probability distribution is given by the median, which has a value of £ 130,021. The lower and upper quartiles receive respective values of £ 17,047 and £ 1,0433,772.

In addition to being positively skewed, third party compensations have also been widely dispersed. The smallest compensation amount has been £ 741 and the largest £ 270,879,622, thus resulting in a range of values of £ 270,878,882. The explanation for such a wide dispersion is in the variety of claims accepted in this category. In some cases compensation might only be paid for fishery-related damage, where as in other cases several types of claims contribute to the total compensation amount. The more different types of claims that are applicable for an individual incident, the more likely it is for the incident to generate higher compensation amounts for third party damage.

Table 7. A summary of the statistical key figures for third party compensations.

Key Figures: Clean-up Costs	
Mean	9 163 923
Median	130 021
Standard deviation	33 769 373
Skewness	6.0447
Area	270 878 882
Minimum	741
Maximum	270 879 622
Q1	17 047.248
Q4	1 043 771.783
Number of Values	88

Because the data for both oil spill clean-up costs and third party compensation was obtained from the same source, it can be assumed that they are comparable with each other. For this reason it is a point of interest to compare the dispersion of values in these variables. By doing so, it is possible to compare the level of their uncertainties. This evaluation can be done by calculating the coefficient of variation. This coefficient adjusts for the different magnitudes of the two variables and thus making them comparable. Oil spill clean-up costs have a coefficient of variation value of 5.37 and the respective value for third party compensation is 3.69. These results clearly indicate that historically oil spill clean-up costs have been more dispersed than third party oil pollution compensations. If dispersion is used as a measure of a variable's uncertainty, then it can be stated that the values of oil spill clean-up costs are more uncertain than third party compensations. This statement is confirmed if also the range of values and standard deviations of the variables are compared.

As mentioned before, there are all together six different types of claims, which are in this study categorized as third party oil pollution claims. The evaluation of the relationship between these costs and other variables is difficult, if not impossible, precisely for this reason. For example, such an analysis as was carried out to test the relationship between oil spill clean-up costs and the amount of oil spilled could be done, but it would prove to be pointless. This is due to the fact that there are even more variables affecting the values of third party compensations, than there are affecting clean-up costs. Of course it is feasible to hypothesize that a larger spill has the potential of generating more third party damages, but then several critical elements will have been overlooked. More so than the amount of oil spilled, these costs are influenced by for example the location and the time of occurrence of the spill as well as the type of oil spilled. A small spill near an area with dense marine agriculture will result in higher third party compensations than a bigger spill occurring under favourable sea conditions in a remote area. This very problem makes even the technical assessment of claims often demanding and time consuming work. To aid in this process a great deal of emphasis in previous research has been devoted to finding a statistical approximation for the relationships between different variables in numerous situations. So far, the results have been slim. Several simulation models have been created by experts in different fields, but so far no one has been able to produce a realistic model.

5.5 Costs from the Loss of Oil

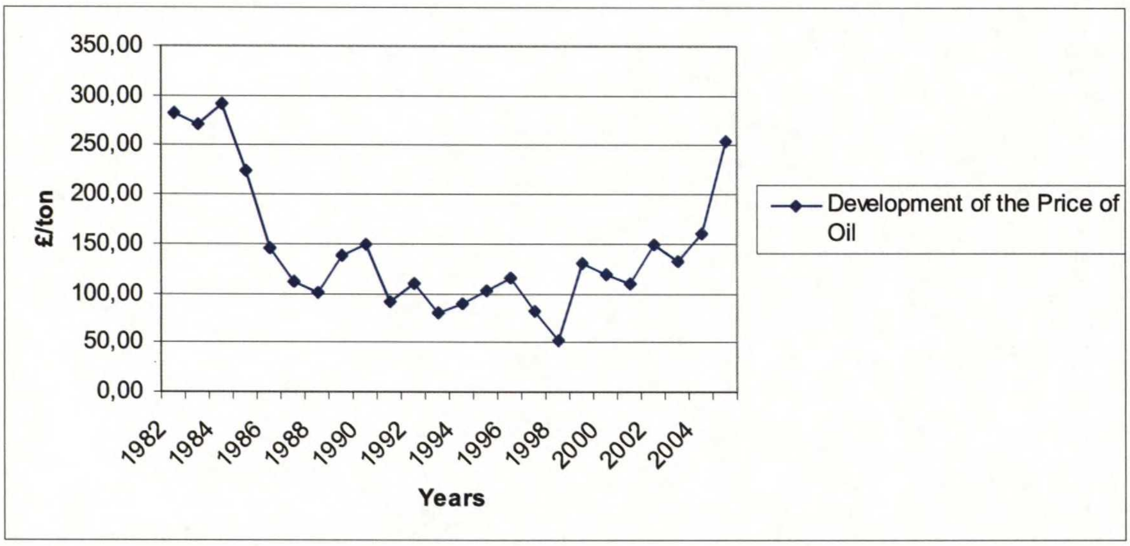
An important issue in determining the financial impact of cargo loss in an oil spill is the fact that all major oil companies have adopted a policy of self insuring their cargo, i.e. big oil companies have not taken outside insurance for their cargo to cover its loss in an oil spill situation. Oil companies have adopted this policy, because according internal calculations the risk of a major incident occurring is so low in respect to the high cost of having such insurance, that it is more economical to self insure the oil.

Because of the policy to self insure transported oil, the two variables which determine the cost of oil lost in an oil spill situation are the amount of oil spilled and the price of oil at the particular time of the spill. The cost for the loss of oil will thus be determined by multiplying the values of these two variables.

In order to obtain a probability function for the cost of oil loss, a simulation model is constructed. The simulation model will randomly pick a value from the probability distribution for the price of oil and then multiply this value with a randomly chosen quantity of oil from its probability distribution. This process is repeated several times and as a result a probability function for the cost of oil will be obtained.

To represent the quantity of oil, the probability distribution from the IOPC Fund oil spill incidents will be used. The oil price data used was obtained from the Thomson Financial DataStream database. The specific oil price used was the crude oil-Brent FOB. The year ending values from the years 1982 to 2005 were selected, because no oil prices were available before that date. The original prices were shown as US$/BBL. In order for the analysis to be comparable with other sections of this study, the prices were converted into Pounds Sterling and corrected for inflation in the same manner as the data utilised in the previous sections. As the amounts of oil spilled are presented in tonnes in the IOPC Funds incident data, the oil prices also had to converted into a £/ton value. The conversion rate used was 1 ton = 7.33 BBL. This is an average conversion rate suggested by the Society of Petroleum Engineers. The exact conversion rate may vary from this figure depending on the type of oil and its density.

Graph 5. The development of the price of oil during the years 1982 to 2005. The oil prices are presented as a £/ton figure.



Because the two variables in the simulation are oil price and oil quantity, it is only natural to assume that they are totally independent of each other. Before the simulation can be performed, the probability distribution of the individual variables has to be evaluated. It will be assumed that the price of oil is normally distributed. From the historical data the following parameters for the normal distribution can be calculated: lower limit = 52.04 £/ton, upper limit = 292.17 £/ton, mean = 172.105 £/ton and standard deviation = 40.022 £/ton. The Microsoft Excel spreadsheet program will randomly generate values for the price of oil from a normal distribution according to the above parameters.

For the random sampling of oil quantities, the RAND () function available in Microsoft Excel will be utilised. This function randomly generates values between 0 and 1. Because the quantities of oil can not be considered normally distributed, but very much positively skewed (skewness coefficient = 5.02), the different probabilities have to be taken into consideration. This is done by dividing the quantities of oil spilled into four classes

Class 1 =	0	–	194	tonnes,	p = 0 – 50 %
Class 2 =	195	–	849	tonnes,	p = 50 – 75 %
Class 3 =	850	–	6,199	tonnes,	p = 75 – 90 %
Class 4 =	6,200	–	84,000	tonnes,	p = 90 – 100 %

The random sampling was carried out in the following way. First, individual columns in the spreadsheet program were selected for each separate function, in this case columns D, E and F. In column D, just a RAND () function was added. In column E, a function was added, which would give as a result a number from 1 to 4, depending on the above probabilities and the value in column D. The following is and example of this function:

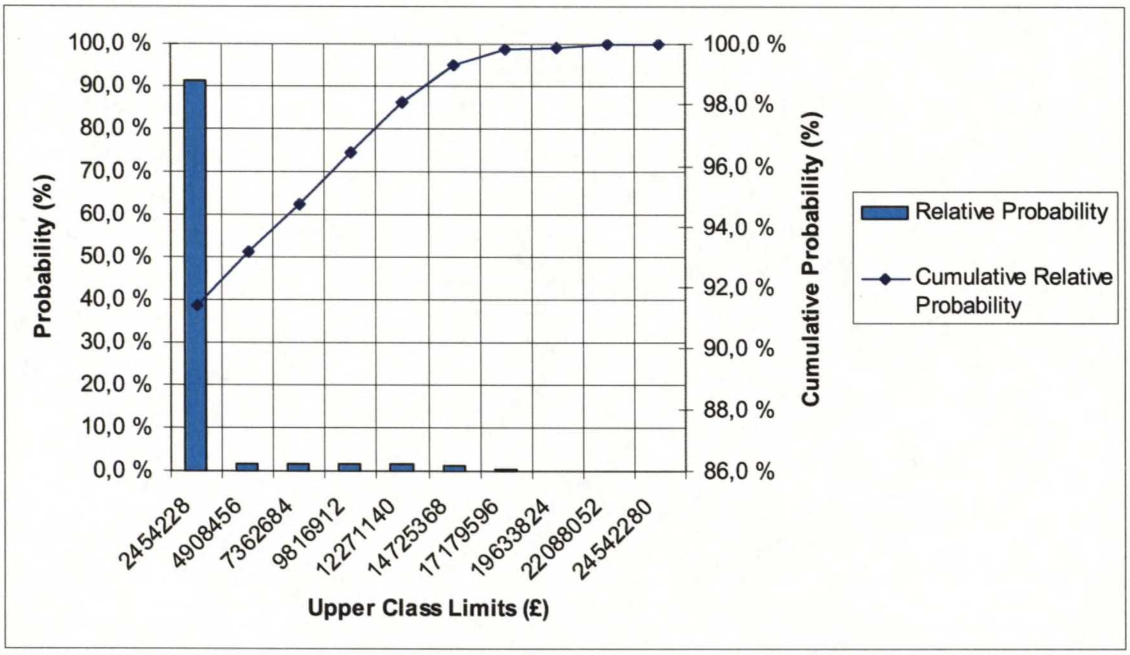
```
IF(D2<0,5;1;IF(AND(D2>=0,5;D2<0,75);2;IF(AND(D2>=0,75;D2<0,9);3;4)))
```

The function in column F randomly selected a value from the class, which was determined by the result of the function in column E. The following is an example of this function:

```
IF(E2=1;194*RAND();IF(E2=2;195+RAND()*654;IF(E2=3;850+RAND()*5349;6200+RAND()*77800)))
```

Thus a result for a random sampling of the quantity of oil was obtained. The pair results from the random sampling of oil prices and quantities of oil were then multiplied into a separate column. Below are presented the results of the simulation with 4,000 iterations.

Graph 6. The results of the cost from the loss of oil simulation presented as relative probabilities and cumulative probabilities. The values obtained from the simulation have been divided into ten classes, with an equal width of £ 2,454,228.



As the graph clearly displays the costs from the loss of oil are positively skewed, with a skewness coefficient of 3.90. This is a result of the positively skewed probability distribution of oil quantities, which the normal distribution of oil prices had a little bit of a levelling effect. This is why the skewness coefficient is lower in the simulation results than in the probability distribution of oil quantities. The majority of the costs resulting from oil loss can be labelled small, because the median of the distribution is £ 38,808. The theoretical maximum of these costs is £ 24,542,280 and theoretical minimum is £ 0, because in one of the incidents no oil was actually spilled, but compensation was paid for pre-emptive measures. The maximum value is obtained by multiplying the highest amount of oil spilled (84,000 tonnes) and the highest price of oil (292.17 £/ton). However, as the results of the simulation show, the probability of such an occurrence is minimal.

5.6 Image Costs

5.6.1 Event Study Methodology

The image costs of oil pollution will be examined by evaluating the effect oil spills have on the share prices of publicly listed oil companies. The ideal situation would be to consider each oil spill independently and determine the effect of that spill on the share price of the specific cargo owner involved in said accident. However, such an analysis is not feasible due to the challenges of obtaining information about the cargo owners involved in oil spills. Usually the cargo owner is not mentioned in reports related to these accidents and thus obtaining such information is a rarity. For this reason, the analysis will be carried out by evaluating the effects of oil spills on a global index of gas and oil companies. The daily index returns used were from the World DataStream Oil & Gas –index obtained from the Thompson Financial DataStream database.

The analysis method utilised is the event study method. The usefulness of an event study is based on the fact that, given rationality in the marketplace, the effect of an event will be reflected immediately in asset prices. This enables for the event's economic impact to be measured over a relatively short period of time. In other words, the change in value of the company is caused by the event. The event study process can be categorised as consisting of five steps: (Henderson 1990, 284)

1. Define the date when the market would have received the news of the event.
2. Characterize the returns in the absence of this news.
3. Measure the size of abnormal returns.
4. Aggregate the abnormal returns.
5. Run statistical tests on the results.

Event definition / Event window: The first step in an event study is to define the event of interest. The event window is related to this and refers to the period of time over which the asset prices of the companies involved are analyzed.

Normal and abnormal returns: In order to evaluate the financial impact of the event, it is necessary to measure the abnormal returns attributable to the event. The abnormal return is defined as the actual return of the security over the event window minus the normal return of the security over the event window. The normal return is the defined as the return that would be expected if the event had not taken place.

In order to measure normal returns, it is necessary to first choose between using a statistical or economic approach. If a statistical approach is chosen, then the two most popular methods are the constant mean return model and the market model. The constant mean return model assumes that the mean return of a security is constant through time, as the name implies. The market model assumes that there is a linear relationship between the market return and the return of the security. Examples of economic models are the capital asset pricing model (CAPM) and versions of the arbitrage pricing theory (APT). However, previous studies have suggested that there exists no good reason to use an economic model instead of a statistical model (Campbell et. al. 1997, 157).

In estimating normal returns, a related subject is defining the *estimation window*, which is the period of time over which the normal return of the security is defined. If possible, the event window is chosen as a period prior to the event window, so that the event window and estimation window do not overlap. An overlapping of the estimation and the event window would cause for the event returns having an effect on the calculation of the expected returns, which would in return prove problematic for the calculation of abnormal returns.

After the individual abnormal returns for each day of the event window and for each individual event have been calculated, it is necessary to calculate the average abnormal return AR_t on day t of the event window, which can be written in mathematical form as (Riihiranta 2003, 49)

$$AR_t = \frac{\sum_{i=1}^{n} AR_{i,t}}{n} \quad , \tag{5}$$

where $AR_{i,t}$ is the abnormal return of event i on day t in the event window. The averaging of the abnormal returns enables the drawing of overall inferences of the event of interest (Campbell et. al. 1997, 160). The total impact of the event can be illustrated with the cumulative abnormal daily return (CAR) across the event window (Riihiranta 2003, 49). The CAR from T_0 to day T_1 can be calculated as

$$CAR_{T_0}^{T_1} = \sum_{t=T_0}^{T_1} AR_t \quad , \tag{6}$$

where AR_t is the average abnormal return on day t in the event window. The examination of both AR_t and CAR are of more importance in the evaluation of the possible abnormal returns generated by oil spill incidents than the possible abnormal returns of individual incidents. The possible image cost effects of oil spill will be interpreted on the basis of the values of these average figures.

Performing statistical tests on the values of abnormal returns obtained as a result of the event study, is necessary to ensure that at a given level of confidence, the results are not purely coincidental. For this reason, the significance levels of the observed abnormal returns are analyzed. The statistical tests on the results of the event study performed in this study will be done according to the manner presented by Brown & Warner (1985, 7). The statistical significance of the abnormal return on day t of the event window (AR_t) is assed by calculating the t-statistic, which is the ratio between AR_t and its estimated standard deviation.

$$\text{t-statistic} = \frac{AR_t}{\hat{s}(AR_t)} \tag{7}$$

The standard deviation is estimated from the 250 –day estimation period as follows:

$$\hat{s}(AR_t) = \sqrt{\frac{\sum_{t=-252}^{t=-3} (AR_t - \overline{AR})^2}{249}}\,, \tag{8}$$

$$\overline{AR} = \frac{\sum_{t=-252}^{t=-3} AR_t}{250} \tag{9}$$

The null hypothesis tested is that the abnormal return on day *t* is equal to zero. It is also assumed that the abnormal returns are independently and identically distributed. The null hypothesis is that the event has no impact on the return of the index. The test statistic is distributed Student-*t* under the null hypotheses.

The t-statistic for the cumulative average abnormal returns (CAR) over a longer time interval in the event window is calculated in a similar manner as follows (Brown & Warner 1985, 29)

$$\text{t-statistic} = \frac{CAR_{T_0}^{T_1}}{\sqrt{\sum_{t=T_0}^{T_1} \hat{s}^2 (AR_t)}} \tag{10}$$

5.6.2 Data and Results

The events of interest in this study are the oil spill incidents presented in the IOPC Fund's 2005 annual report and the event dates are considered to be the dates stated in that information. Because oil spills can be considered an unexpected event, the event window will consist of 2 days prior to the event date and 5 days after the event date. So the event window will be [-2, +5] in relation to the event date. Extending the event date to 2 days prior to the incident will aid in the visual assessment of the effects of oil spills. The estimation period will consist of a time period of 250 days prior to the event window, i.e. [-252,-3] in relation to the event date.

This study will define the normal returns with the constant mean return model. Although the constant mean return model is the simplest model available, it yields results similar to those of more sophisticated models (Campbell et. al. 1997, 154). The evaluation of the event study results will consist of a graphical and statistical analysis.

The total sample of oil spills incidents used in the event study consisted of 53 incidents. The sample was formed by the oil spill incidents in the IOPC Fund information, where the registered spill amount was over 100 tonnes. In two cases, an incident overlapped with the event window of another event and so these incidents were disregarded, in order to maintain the abnormal returns independent across events. In addition to these 51 incidents, the oil spill of Exxon Valdez, which was not mentioned in the IOPC Fund information and the oil spill of Prestige, for which the IOPC Funds did not offer an amount of spilled oil, were also included in the event study. This decision was made, because even though for the reasons stated they were not included in the original sample, they are still considered significant oil spills by the experts in this field.

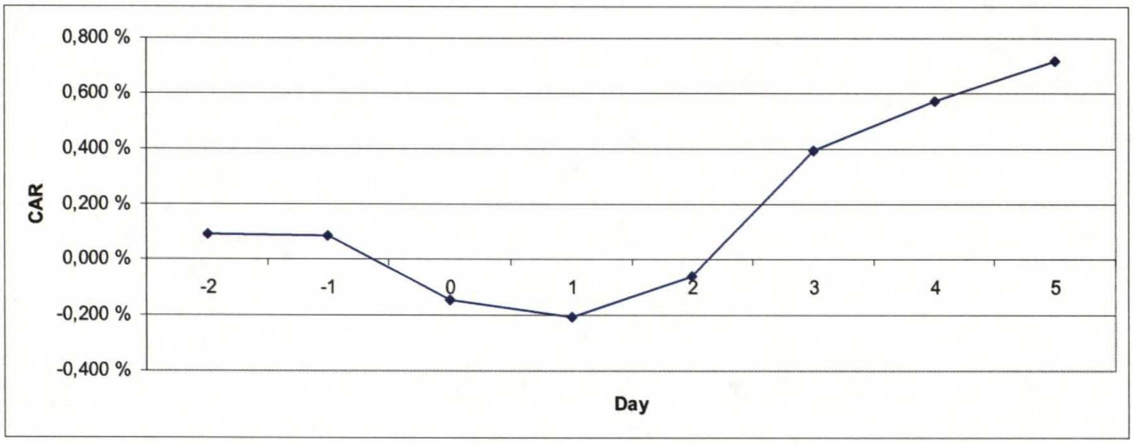
Table 8 shows the averaged abnormal returns across the total sample of 53 oil spill incidents and the values for the cumulative average abnormal returns (CAR). Graph 7 graphically illustrates the development of CAR values for the total 8-day event window.

Table 8. The daily average abnormal returns (AR_t), cumulative average abnormal returns (*CAR*) and the t-statistics for AR_t for the entire sample of 53 oil spill incidents. These are followed by the values of *CAR* and the respective t-statistics for different intervals within the event window.

Day relative to oil spill	AR_t	CAR	t-statistic of AR_t
-2	0.091%	0.091%	0.117
-1	-0.004%	0.087%	-0.005
0	-0.232%	-0.145%	-0.301
1	-0.062%	-0.208%	-0.081
2	0.151%	-0.057%	0.195
3	0.453%	-0.396%	0.587
4	0.175%	0.571%	0.226
5	0.149%	0.720%	0.193

Interval	-2 to +5	-1 to +4	-1 to +3	-1 to +2	-1 to +1	-1 to 0
CAR	0.720%	0.481%	0.306%	-0.147%	-0.298%	-0.236%
t-statistic of CAR	0.330	0.254	0.177	-0.096	-0.223	-0.216

Graph 7. The development of CAR during the 8-day event window for the entire sample of 53 oil spill incidents.



The results of the event study suggest that the occurrence of an oil spill accident has a negative effect on the image of oil companies. This conclusion can be drawn from the negative abnormal returns of both days 0 and +1. A negative abnormal return on day +1 captures the market effects of such oil spills that have come to the attention of the markets after the trading day of day 0 and thus are conveyed in the abnormal returns of day +1. However, the abnormal returns reflecting the effect of oil spills on the values of oil companies seems to be rather small. In addition to being relatively small, based on the development of *CAR* values after the event date, the negative effects can also be described as temporary. As soon as on day +3, in relation to the incident, the *CAR* value has returned to positive.

The statistical significance of the results of the event study is at a relatively high level. At the significance level of 0.05, as was already previously used in this paper, all the results are statistically significant. The results are also statistically significant if a higher significance level of 0.01 is assumed.

6 DISCUSSION

The analysis of the uncertainty in total oil pollution costs is somewhat aided by the fact that all the individual variables can be considered independent from each other. In certain situations there would seem to appear to be a correlation between clean-up costs and third party compensations, but making such an assumption would prove to be erroneous. The indication of a positive correlation is in fact caused by a common denominator, the amount of oil spilled. This in some instances may be positively correlated with both of the variables.

Based on the risk analysis carried out in the previous chapter, it is possible to state that the most uncertain cost factor are the costs of oil spill clean-up. This variable has the possibility to generate very high costs and the range of values is also the widest. However, as is the case also with the other variables, the probability of these costs being of a significant amount is rather small and the majority of values are concentrated on the lower end of the distribution. Despite this, it is my opinion that this variable is the one in which the new oil spill response concept of Corporation X may have the most impact on. Answering the question of how significant an impact, is however impossible for the author to comment on. It can only be said that the impact will be dependent on the concept's capability to decrease oil spill response time, because all of the other variables, such as the quantity of oil spilled, the location of the spill and the type of oil spilled, are out of the influence of any oil spill response program. Oil spill response time is the only one that can be influenced by external resources.

This being said, it is necessary to point out that OSRL has already noticed this. For this reason they have given considerable emphasis to the co-ordination and arrangement of their logistical operations. They have taken measures such as pre-packaging equipment and clearing them with customs. These measures aim for the most rapid deployment possible. The only weak spot in the operations of OSRL is the fact that their resources can only be deployed from two locations. This is some situations results in long transportation times. By setting up more bases on a global scale, transportation times could be decreased and the response measures would be more effective and clean-up costs would possibly be lowered. However, this solution has a problem of its own. As mentioned before, this business suffers form somewhat of lack in professional personnel and the more oil spill response centres there are; the higher is the need for such personnel. Acquiring the needed personnel will probably raise personnel costs which will have to be passed on to the customers and as an end result the advantage gained in more effective response would be lost in higher fees.

The uncertainty in third party compensation amounts was also particularly high. In extreme situations, these costs could also be considerable, but the majority of incidents resulted in only relatively small compensation amounts. However, the uncertainty of these costs may rise in the future, because according to the representative of the IOPC Funds, the array of claims, which are being accepted in to this category, is experiencing a expanding trend and this trend is likely to continue in the future. This would mean that if even more different types of third party oil pollution damages are accepted, the level of third party compensations will rise. This rise would be then passed on to oil companies by higher calls of P&I clubs and contributions to the IOPC Funds.

A factor which will restrain the rise in third party costs is the existence of the International Tanker Owners Pollution Federation (ITOPF). ITOPF is an independent consulting organization with expertise in the technical assessment of third party claims. They for example work in close co-operation with tanker owners and their insurers in oil spill situations, to assess the basis on which claims are made and if the claims are reasonable. This way the insurers and the tanker owners will know what would be reasonable settlement amounts when compensations are negotiated. The existence of such an independent organization, guarantees that is some control in what compensations are paid and the compensation amounts.

The two oil pollution cost variables which Corporation X has the least control over and in which the impact of their oil spill response service would possibly be the smallest are the costs from the loss of oil and image costs. The costs from the loss of oil are more determined by the uncertainty in the quantity of oil spilled than in the fluctuations of oil prices. The ability to lower these costs would rely on the technological developments of oil clean-up equipment and the ability of this equipment to collect the oil in a form that is still beneficial to the owner. The equipment currently used, at least the equipment used by OSRL, are not able to carry out such procedures in an effective manner.

Previous research attempting to estimate the image costs of oil pollution on cargo owners is to my knowledge to this point non-existent. The possibilities for future research to provide a definitive answer to the problem of isolating the image costs of an oil spill to an individual oil company seem challenging. Based on the results of this study, it can be concluded that there exists at least a temporary negative effect on the whole of the oil industry caused by an oil spill. However, it is certain that oil spills will not have a wider negative impact on cargo owners if the information of who these cargo owners are does not become more publicly available. Another challenge in evaluating these costs arises from the fact that image costs might not be generated by an individual incident, but as a "snowball" effect of several incidents related to one company. This point was raised in the interview with the representative of BP. If however the responsibility of cargo owners in oil spill situations becomes more widely recognised, this might not only increase image costs, but oil spill clean-up costs as well, because more public interest might influence the oil companies to focus more resources on clean-up operations than is "necessary" for the benefit of PR.

All in all, there is a general feeling amongst the professionals interviewed for this research that there exists the possibility that total oil pollution costs will decrease in the future. This opinion was shared by many of the experts interviewed for this research. The main reason for a possible decline is the positive trend in accidents, which has been visible for some time now. A positive accident trend in this instance refers to less and less oil spill accidents occurring. The level of all of the four individual costs are, at least in theory, dependent on the number of oil spills and thus a decline in the number of oil spills, would also be passed on as a decline in all of the individual cost factors. An important factor in the positive trend of accidents is the increasingly rigorous vetting process. The vetting process is an assessment of the vessels offered by charter companies which the oil companies use in situations when the capacity of their own fleet is insufficient. As the demands of the oil companies grow, the charter companies have to put more emphasis on the quality of their vessels, which in turn leads to fewer accidents.

It is important though to stress that the scenario of all of the oil pollution related costs being flexible both upwards and downwards holds true in theory. This is a realistic assumption is the case of all other cost factors except the calls paid to P&I clubs. Based on the information received, the calls made by P&I clubs should be flexible both ways. In reality though there is a higher probability that calls will be more easily raised than lowered.

The most important limitation to this study was presented by the availability of relevant quantitative information. Better co-operation from certain parties would have increased the level of realism of this study and ultimately a complete risk analysis could have been carried out. Such co-operation in light of further research is in my view extremely unlikely. The information needed to complete the intended risk analysis would require information which is considered so confidential, especially from the part of the P&I clubs, that even stakeholders interacting with these clubs on regular bases, do not have access to that information. One of the objectives of this study was to use risk analysis techniques to study the uncertainty in a phenomena presented in environmental economics literature. Although this goal was not completely fulfilled, in terms that a complete sensitivity and simulation analysis was not possible to carry out, in my view this study still succeeded in combining these two areas of economics and contributing to the existing literature in both of these areas.

The other limitations of this study are also limited to the information used and the prevailing legal framework. In the IOPC Fund incident information it was not specified when individual compensation amounts were made. For this reason a compromise of assuming that all payments were made at the end of the year when the incident occurred had to be made. The discrepancy between this assumption and the actual compensation times is problematic because it is impossible to use the correct exchange rates and the appropriate inflation coefficients.

Because all the countries in the world have not ratified the 1992 CLC and thus become members of the IOPC Funds, it is not possible to expand the scope of this study to cover all oil spill incidents around the world. The scope of this study is only restricted to incidents occurring in countries members of the IOPC Funds. However, in this context this study does provide a good illustration of the framework of how oil pollution costs are formed in these countries.

Because the ultimate goal of Corporation X is to provide a service which would attract customers presently members of OSRL and thus comparing the benefits of this concept to OSRL is essential. The aim of this study was to provide Corporation X with information on what cost benefits the new system would provide oil companies. It became increasingly evident during this research that the economic factor of having OSRL as an oil spill service provider for a global company is of little importance. When the membership costs of OSRL are put into the perspective of the total operations of a global oil company, the financial impacts are insignificant. The strength of OSRL in the eyes of oil companies lies in other areas. For example BP considers OSRL as being the only organization which can provide this type of service on the scale and the level of reliability and effectiveness, which they require. The restricting aspect of available professionals and specific equipment to carry out oil spill response operations, already mentioned several time during the course of this paper, can also be incorporated into this scenario of challenges. Based on these assessments, it is my opinion that the forces most influencing the success of the investment of Corporation X from this perspective are situated not in the economic field, but in other areas such as competitive, technological and social forces.

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London 3.7.2006, *Secretary and Executive Officer*, International Group of P&I Clubs

APPENDICES

Appendix 1. A list of member countries of the 1992 Fund.

Member Countries of the 1992 Fund (2.5.2006)	
Albania (enters into force 30/06/06)	Luxembourg (enters into force 21/11/06)
Algeria	Madagascar
Angola	Malaysia
Antigua and Barbuda	Maldives (enters into force 20/05/06)
Argentina	Malta
Australia	Marshall Islands
Bahamas	Mauritius
Bahrain	Mexico
Barbados	Monaco
Belgium	Morocco
Belize	Mozambique
Brunei Darussalam	Namibia
Bulgaria (enters into force 18/11/06)	Netherlands
Cambodia	New Zealand
Cameroon	Nigeria
Canada	Norway
Cape Verde	Oman
China (Hong Kong Special	Panama
Administrative Region)	Papua New Guinea
Colombia	
Comoros	Philippines
Congo	Poland
Croatia	Portugal
Cyprus	Qatar
Denmark	Republic of Korea
Djibouti	Russian Federation
Dominica	Saint Kitts and Nevis
Dominican Republic	Saint Lucia
Estonia	Saint Vincent and the Grenadines
Fiji	Samoa
Finland	Seychelles
France	Sierra Leone
Gabon	Singapore
Georgia	Slovenia

Germany	South Africa
Ghana	Spain
Greece	Sri Lanka
Grenada	Sweden
Guinea	Switzerland (enters into force 10/10/06)
Iceland	Tonga
India	Trinidad and Tobago
Ireland	Tunisia
Israel	Turkey
Italy	Tuvalu
Jamaica	United Arab Emirates
Japan	United Kingdom
Kenya	United Republic of Tanzania
Latvia	Uruguay
Liberia	Vanuatu
Lithuania	Venezuela

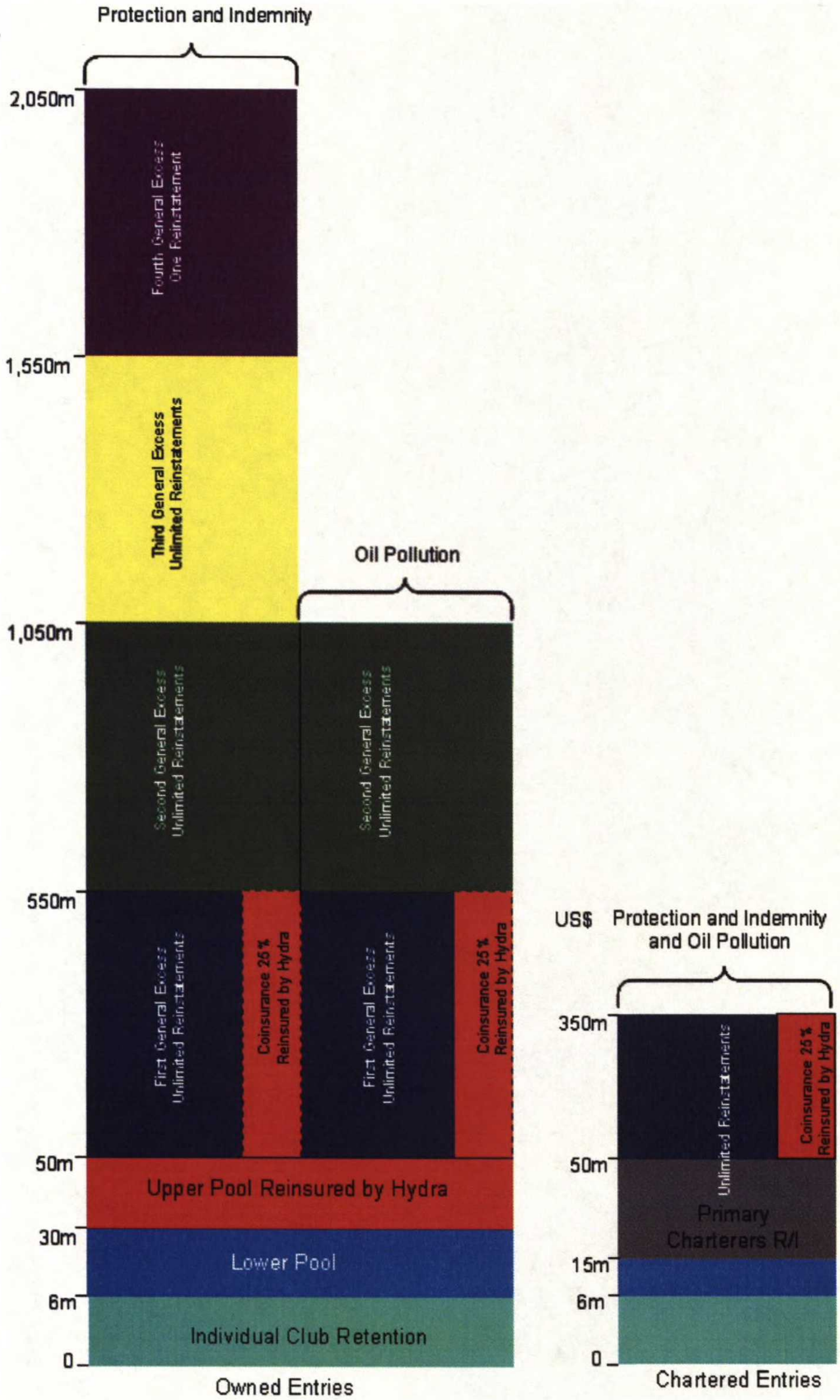
Source: www.iopcfunds.org/92members.htm

Appendix 2. A list of member countries of the Supplementary Fund.

Member Countries to the Supplementary Fund (2.5.2006)	
Barbados	Lithuania
Belgium	Japan
Croatia (enters into force 17/05/06)	Netherlands
Denmark	Norway
Finland	Portugal
France	Slovenia (enters into force 03/06/06)
Germany	Spain
Ireland	Sweden
Italy	

Source: www.iopcfunds.org/92members.htm#supfund

Appendix 3. The chart of reinsurance from the Pooling Agreement of the IGP&I.



Source:www.igpandi.org/internal.php?primary_nav_selected=The+Group+Agreements&secondary=Pool+reinsurance+programme

Appendix 4. The contribution formula stipulating the contribution amount of the individual group clubs to pooled claims.

$$z = \frac{\frac{(100*b)}{a} + \frac{(100*d)}{c} + \frac{(100*e)}{f}}{3} \text{, where} \qquad (11)$$

z = the percentage of the apportionable loss (first tranche) to be borne by the Association
a = the total relevant income received by all the Associations
b = the relevant income received by the subject Association
c = the total relevant tonnage entered in all the Associations
d = the total relevant tonnage entered in the subject Association
e = the total amount of the relevant claims paid and estimated by all the Associations
f = the total amount of relevant claims paid and estimated by the subject Association

Source: Interview with Secretary and Executive Officer International Group of P&I Clubs.

Appendix 5. Table containing the incident data of the IOPC Funds.

Number	Ship	Date	Place	Quantity of spill	Clean-up Costs	Other Compensati-on
1	Antonio Gramsci	27.2.1979	USSR	5500	27 577 146	
2	Miya Maru # 8	22.3.1979	Japan	540	542 079	204 419
3	Tarpenbek	21.6.1979	UK	n/a	965 954	
4	Mebaruzaki Maru # 5	8.12.1979	Japan	10	37 328	14 588
5	Showa Maru	9.1.1980	Japan	100	50 338	458 127
6	Tanio	7.3.1980	France	13500	47 521 232	645 322
7	Furenas	3.6.1980	Sweden	200	783 980	34 372
8	Hosei Maru	21.8.1980	Japan	270	788 562	286 369
9	Jose Marti	7.1.1981	Sweden	1000	4 086 465	
10	Suma Maru # 11	21.11.1981	Japan	10	32 408	9 324
11	Globe Asimi	22.11.1981	USSR	16000		518 544
12	Ondina	3.3.1982	Germany	300	5 785 550	
13	Shiota Maru #2	31.3.1982	Japan	20	240 065	134 919
14	Fukutoko Maru # 8	3.4.1982	Japan	85	1 034 449	869 281
15	Kifuku Maru # 35	1.12.1982	Japan	33		3 087
16	Shinkai Maru # 3	21.6.1983	Japan	3,5	5 598	2 619
17	Eiko Maru # 1	13.8.1983	Japan	357	129 162	63 503
18	Koei Maru # 3	22.12.1983	Japan	49	100 297	54 268
19	Tsunehisa Maru # 8	26.8.1984	Japan	30	99 334	1 442
20	Koho Maru # 3	5.11.1984	Japan	20	410 308	160 563
21	Koshun Maru # 1	5.3.1985	Japan	80	152 013	2 759
22	Patmos	21.3.1985	Italy	700		8 080 525
23	Jan	2.8.1985	Denmark	300	1 234 758	51 456
24	Brady Maria	3.1.1986	Germany	200	1 867 541	
25	Take Maru # 6	9.1.1986	Japan	0,1		741
26	Oued Guetirini	18.12.1986	Algeria	15	126 194	253 159
27	Thuntank 5	21.12.1986	Sweden	200	3 826 606	121 363

28	Antono Gramsci	6.2.1987	Finland	700	398 291	
29	Southern Eagle	15.6.1987	Japan	15	246 790	359 721
30	El Hani	22.7.1987	Indonesia	3000	205 756	
31	Akari	25.8.1987	UAE	1000	357 491	
32	Hinode Maru	18.12.1987	Japan	25	12 897	1 061
33	Amazzone	31.1.1988	France	2 000	159 786	20 413
34	Taiyo Maru # 13	12.3.1988	Japan	6	41 646	4 203
35	Czantoria	8.5.1988	Canada	n/a	1 273 326	
36	Kasuga Maru # 1	10.12.1988	Japan	1 100	2 524 356	392 054
37	Nestucca	23.12.1988	Canada	n/a	7 461	
38	Fukkol Maru # 12	15.5.1989	Japan	0,5	3 097	3 455
39	Tsubame Maru # 58	18.5.1989	Japan	7		125 124
40	Tsubame Maru # 16	15.6.1989	Japan	n/a		4 255
41	Kifuku Maru # 103	28.6.1989	Japan	n/a	52 092	2 714
42	Nancy Orr Gaucher	25.7.1989	Canada	250	227 893	
43	Dainichi Maru # 5	28.10.1989	Japan	0,2	2 317	17 867
44	Daito Maru # 3	5.4.1990	Japan	3	28 699	3 261
45	Kazuei Maru # 10	11.4.1990	Japan	30	255 510	7 473
46	Fuji Maru # 3	12.4.1990	Japan	n/a	504	6 994
47	Volgoneft 263	14.5.1990	Sweden	800	1 954 813	166 914
48	Hato Maru # 2	27.7.1990	Japan	n/a		6 735
49	Bonito	12.10.1990	UK	20	177 861	
50	Rio Orinoco	16.10.1990	Canada	185	7 837 532	
51	Portfield	5.11.1990	UK	110	341 534	36 987
52	Vistabella	7.3.1991	Carribean	n/a	1 136 446	
53	Hokunan Maru # 12	5.4.1991	Japan	n/a	11 933	27 615
54	Agip Abruzzo	10.4.1991	Italy	2 000		1 020 197
55	Kaiko Maru # 86	12.4.1991	Japan	25	301 233	243 281
56	Kumi Maru # 12	27.12.1991	Japan	5	5 947	4 304
57	Fukkol Maru # 12	9.6.1992	Japan	n/a		32 291
58	Aegean Sea	3.12.1992	Spain	73 500	17 859 048	86 242 193

59	Braer	5.1.1993	UK	84 000	726 664	62 824 873
60	Kihnu	16.1.1993	Estonia	140	77 632	
61	Sambo # 11	12.4.1993	Rep.of Korea	4	181 222	43 903
62	Taiko Maru	31.5.1993	Japan	520	5 607 954	2 546 953
63	Ryoyo Maru	23.7.1993	Japan	500	62 491	52 068
64	Keumdong # 5	27.9.1993	Rep. of Korea	1 280	5 739 958	13 626 926
65	Iliad	9.10.1993	Greece	200	1 181 430	10 258 620
66	Daito Maru # 5	11.6.1994	Japan	0,5	9 065	6 464
67	Toyotaka Maru # 5	17.10.1994	Japan	560	4 806 434	661 784
68	Hoyu Maru # 53	31.10.1994	Japan	n/a	1 549	32 275
69	Sung Il # 1	8.11.1994	Rep.of Korea	18	9 082	27 416
70	Spill from unknown sour-ce	30.11.1994	Morocco	n/a	222 088	
71	Dae Woong	27.6.1995	Rep. of Korea	1	41 358	
72	Sea Prince	23.7.1995	Rep.of Korea	5 035	27 686 833	27 094 569
73	Yeo Myung	3.8.1995	Rep.of Korea	40	650 067	1 144 299
74	Shinryu Maru # 8	4.8.1995	Japan	0,5	61 825	11 210
75	Senyo Maru	3.9.1995	Japan	94	2 250 204	369 791
76	Yuil # 1	21.9.1995	Rep.of Korea	n/a	18 264 134	7 565 580
77	Honam Sapphire	17.11.1995	Rep.of Korea	1 800	8 584 879	1 165 179
78	Sea Empress	15.2.1996	UK	72 360	25 588 169	17 829 269
79	Kugenuma Maru	6.3.1996	Japan	0,3	11 208	1 680
80	Kriti Sea	9.8.1996	Greece	30	2 187 005	1 114 498
81	# 1 Yung Jung	15.8.1996	Rep.of Korea	28	559 277	39 606
82	Tsubame Maru # 31	25.1.1997	Japan	0,6	40 098	2 391
83	Nissos Amorgos	28.2.1997	Venezuela	3 600	4 877 389	73 127 047
84	Daiwa Maru # 18	27.3.1997	Japan	1	2 171 640	4 522
85	Jeong Jing # 101	1.4.1997	Rep.of Korea	124	167 551	23 249
86	Plate Princess	27.5.1997	Venezuela	3,2		31 931 841
87	Diamond Grace	2.7.1997	Japan	1 500	5 747 844	1 651 199
88	Katja	7.8.1997	France	190	2 575 803	67 167

89	Evoikos	15.10.1997	Singapore	29 000	4 384 020	3 022 858
90	Kyungnam # 1	7.11.1997	Rep.of Korea	20	75 845	33 197
91	Pontoon 300	7.1.1998	UAE	4 000	1 176 796	36 657 040
92	Maritza Sayalero	8.6.1998	Venezuela	262	12 000	
93	Alambra	17.9.2000	Estonia	300	455 642	1 783 542
94	Singapura Timur	28.5.2001	Malaysia	n/a	712 070	19 067
95	Incident in Germany	20.6.1996	Germany	n/a	1 215 975	
96	Nakhodka	2.1.1997	Japan	6 200	109 357 499	26 970 353
97	Osung # 3	3.4.1997	Rep.of Korea	n/a	6 545 623	977 467
98	Incident in UK	28.9.1997	UK	n/a	11 179	
99	Santa Anna	1.1.1998	UK	280	33 811	
100	Milad 1	5.3.1998	Bahrain	0	38 218	
101	Mary Anne	22.7.1999	Philippines	n/a	1 756 074	
102	Erika	12.12.1999	France	14 000	14 943 923	109 103 434
103	Al Jaziah 1	24.1.2000	UAE	200	1 280 518	
104	Slops	15.6.2000	Greece	n/a	1 602 790	
105	Incident in Spain	5.9.2000	Spain	n/a	4 140	
106	Incident in Sweden	23.9.2000	Sweden	n/a	409 687	
107	Natuna Sea	3.10.2000	Indonesia	7 000	8 482 374	175 022
108	Baltic Carrier	29.3.2001	Denmark	2 500	7 608 051	1 968 960
109	Zeinab	14.4.2001	UAE	400	1 158 654	
110	Incident in Guadaloupe	30.6.2002	Guadaloupe	n/a	243 532	
111	Incident in UK	29.9.2002	UK	n/a	5 934	
112	Prestige	13.11.2002	Spain	n/a	406 328 387	270 879 622
113	Spabunker IV	21.1.2003	Spain	n/a	4 604 740	
114	Incident in Bahrain	15.3.2003	Bahrain	n/a	415 478	326 835
115	Buyang	22.4.2003	Rep.of Korea	40	509 641	166 000
116	Hana	13.5.2003	Rep.of Korea	34	628 574	21 079
117	Victoriya	30.8.2003	Russian Federati-on	n/a	301 508	
118	Duck Yang	12.9.2003	Rep.of Korea	300	1 459 082	21 762

119	Kyung Won	12.9.2003	Rep.of Korea	100	1 478 313	205 982
120	Jeong Yang	23.12.2003	Rep.of Korea	700	2 020 345	168 733
121	# 11 Hae Woon	22.7.2004	Rep.of Korea	12	186 775	
122	# 7 Kwang Min	24.11.2005	Rep.of Korea	64	2 296	

Source: IOPC Funds Annual Report 2005